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PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTY-SIXTH.

1884-5.

EDITED BY G. H. MORTON, F.G.S.

(The Authors having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART I.—VOL. V.

LIVERPOOL:
C. TINLING & CO., PRINTERS, VICTORIA STREET.

1885.

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OF THE

Liverpool Geological Society.

SESSIONS XXVI.—XXIX.

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LIVERPOOL

C. TINLING AND CO., PRINTERS, VICTORIA STREET.

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PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-SIXTH.

OCTOBER 14TH, 1884.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The Officers and Council for the ensuing year were elected, and the Treasurer read his Annual Report, which had been duly audited.

The President then read his Annual Address:—

THE DENUDATION OF THE TWO AMERICAS.

NOVEMBER 11TH, 1884.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following papers were read:—

THE PRESENCE OF CALCAREOUS SPICULA IN THE TUNICATA.

BY W. A. HERDMAN, D. Sc., F.R.S.E.

DECEMBER 9TH, 1885.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

A. G. HAYWOOD was elected an Ordinary Member.

The following papers were then read:—

THE CONSERVATIVE ACTION OF ANIMALS IN RELATION TO DYNAMICAL GEOLOGY.

BY W. A. HERDMAN, D. Sc., F.L.S.

THE MICROSCOPIC CHARACTER OF THE TRIASSIC SANDSTONES OF THE COUNTRY AROUND LIVERPOOL.

BY G. H. MORTON, F.G.S.

JANUARY 13TH, 1885.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following papers were then read:—

THE GEOLOGICAL ASPECTS OF THE MERSEY TUNNEL.

By T. MELLARD READE, C.E., F.G.S.

FURTHER OBSERVATIONS ON THE CARBONIFEROUS LIMESTONE OF THE NORTH OF FLINTSHIRE.

By G. H. MORTON, F.G.S.

FEBRUARY 10TH, 1885.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following papers were read :—

A QUARRY AT POULTON, AND THE RELATION OF THE GLACIAL MARKINGS THERE, AND OTHERS IN THE NEIGHBOURHOOD.

By HENRY C. BEASLEY.

BORINGS ON THE SOUTHPORT AND CHESHIRE LINES EXTENSION RAILWAY.

By T. MELLARD READE, C.E., F.G.S.

MARCH 10TH, 1885.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The following papers were read :—

ON A SECTION ACROSS THE RIVER DOUGLAS AT HESKETH BANK—A POST-GLACIAL DEPOSIT IN WHICH WERE HUMAN BONES.

By T. MELLARD READE, C.E., F.G.S.

THE MICROSCOPIC CHARACTER OF THE CEFN-Y-FEDW SANDSTONE OF DENBIGHSHIRE AND FLINTSHIRE.

By G. H. MORTON, F.G.S.

DENUDATION

OF THE

TWO AMERICAS,

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

"Whence it appears, not only that in proportion as knowledge becomes quantitative do its previsions become complete as well as certain, but that until its assumption of a quantitative character it is necessarily confined to the most elementary relations."—*Herbert Spencer's Essays, Vol. I., Essay III.*

INTRODUCTION.

When, in 1876, I had the honor to deliver a Presidential Address to this Society, I chose as its subject matter "Geological Time." I then had the pleasure to lay before you some calculations relating to "Chemical Denudation," which at the time possessed some little novelty. Since the information was published it has, to a certain extent, been incorporated with geological literature. The subject was, however, far from being exhausted, nor is it likely to be for many years yet to come. In the meantime, having accumulated additional facts, it will be part of the object of this address to arrange and analyse them, so as to check the original generalizations, and further to illustrate the value in geological speculation of an accurate knowledge of the relative magnitude of the various objects and things dealt with.

* Presidential Address to the Liverpool Geological Society, Session 1874-5.

The importance of a quantitative examination of geological data is not yet properly appreciated. Some of our authorities, as may be seen in quotations from them in manuals and text books, hardly get further in their reasoning than is shewn in the following examples. Suppose it were an attempt to estimate the extent of time during which the Coal-measures were being laid down, the formula would probably be as follows:—"So many feet of mud-sediment were laid down in a century; the Coal-measures are so many thousand feet in thickness; there are such a number of seams of coal of a given thickness, with a thousand years for the formation of each vertical yard, and the result arrived at is 640,000 years." Or say it is an estimate of geological time that is required, then the following appears to be a not unusual method:—"Assuming that $\frac{1}{10}$ of an inch of sediment is laid down in one year, and the total thickness of the whole of the sedimentary rocks is so much, then the time taken in their production is 100,000,000 of years;" or whatever figures this intricate calculation leads to. Whether the result comes out at one hundred or one thousand millions, or only a million years, the results are probably to most people equally incomprehensible, and therefore interesting. Nor need we be surprised, for there are some singular instances extant of inability to grasp the relations of figures when only thousands are dealt with; for instance, in Phillips' "Treatise on Geology," (1839), in vol. ii, p. 8., there is a calculation relating to the sediment laid down by the Ganges, in which the average waste of the drainage basin of the Ganges is estimated at $\frac{1}{40000}$* of a yard, "*which is about* $\frac{1}{11}$ *of*

* It is much more than this.

an inch per annum from the whole surface of the drainage." The final result arrived at is that the whole of the English Tertiaries, averaging 300 feet thick, and 6,000 square miles in extent, could have been laid down by the Ganges in 8,000 years. The fraction should be $\frac{1}{1111}$ and the time, in rough figures, 80,000 years!

I was, however, very much interested when I met with this calculation, for though it appears incorrect in most particulars, it is the first attempt I know of to measure the average waste of the drainage basin of a river. Previously Mr. A. Tylor had the credit of originating this mode of investigation (Changes of the Sea Level, Phil. Mag., 1853), which was more fully worked out by Dr. Geikie (Trans. Geo. Soc. of Glasgow, 1868), and Dr. Croll (in Geo. Time Phil. Mag., 1868)* If Phillips had been in the habit of making these calculations he would have seen at a glance that the result was wrong, and would have checked his figures. To preserve accuracy it is, however, essential to have all calculations checked by another individual, for as far as my experience goes, even mathematicians are no more exempt from errors of calculation than ordinary men.

The worst circumstance connected with these errors is, that they get copied from one book to another without any attempt at verification. Of this I could give numerous instances, but such a course would be invidious, and raise too great a storm about my ears.

It would seem, however, as if the figures possessed little meaning to most people, or the inaccuracies would be more quickly detected, at least by scientific men. For my own part, I can only say I shall feel indebted to any one who may find errors in my own calculations, if he will take the trouble to acquaint me with the fact.

* See Darwin on Earth Worms, p. 233.

With these preliminary remarks I will proceed to inquire in what way an accurate knowledge of the numerical proportions of the materials of rocks, their solid contents and extent in relation to one another, the earth and the ocean, and the rate of accumulation, may affect our entire conceptions of various geological problems.

In my presidential address, 1876-7, I ventured incidentally to remark that Hutton laid the foundations of our present knowledge of physical geology. The reviewer, in *Nature* of my "Chemical Denudation," (October 2nd, 1879) takes exception to this, and says "He gave us the grand method of geological study, but certainly many of the facts were well-known before his time, and others have no relation to his researches or method." Again, Darwin says, "Until the last twenty or thirty years most geologists thought that the waves of the sea were the chief agents in the work of denudation; but we may now feel sure that air and rain, aided by streams and rivers, are much more powerful agents, that is if we consider the whole area of the land." This is true, but it is also true that Hutton had a correct conception of the same truth at the end of the last century; and it seems amazing that his cogent logic and reiterated statements to the same effect were so long in being appreciated and understood. A perusal of the "Theory of the Earth," will well repay the reading even now, and I hope to see the time when a reprint, with full editorial notes, will be offered to the public. At present it is all but inaccessible. The whole theory of subaërial denudation, as at present understood and accepted, is there as clearly laid down, and in as lucid and glowing language as is possible. How Lyell could call his style dry and uninteresting amazes me. To the last Lyell never

thoroughly accepted the Huttonian theory of denudation, which underlies all our modern notions of physical geology in a manner, if not so universal as that of gravitation in relation to astronomy, yet much in the same way. In the tenth edition, 1867, of his immortal "Principles," Lyell says (vol. i. p. 78), speaking of Hutton and Playfair, "They ascribed valleys in general too exclusively to the action of the rivers now flowing in them, not allowing sufficiently for the excavating and transporting power which the waves of the ocean must exert on land during its emergence, nor for those inequalities of the surface which must be produced by movements accompanying the upheaval of the land;" but Hutton himself gives the clue to these misconceptions when he says, "These consolidated masses are resolved in so slow a manner that *nothing but the most philosophical eye, by reasoning on a chain of facts,* is able to discover it"—the italics are mine. But, further, he indicates the way in which his ideas have finally triumphed:—"Nothing is more steady than the resolution of our land, nothing rests upon more certain principles, and there is nothing which in science may be more easily investigated." Notwithstanding this luminous reasoning, the ideas were for a long time considered if not actually false yet exaggerated beyond all bounds of truth; but the demonstration has been complete, and through what?—*through quantitative calculations from ascertained data,* which puts the truth of his generalizations beyond the shadow of a doubt. The amount of detritus brought down by rivers was weighed and gauged by many modern investigators, and found to far outweigh the denudation caused by the waves of the sea. Tylor, Geikie, Croll calculated and proved it; Ramsay, by another line of reasoning, shewed the enormous amount of rock that

had been removed by subaërial denudation in the mountainous parts of Wales; and Mr. Whitaker followed it up by very original reasoning on the origin of escarpments. I venture to think that my own investigations of chemical denudation, a previously unworked mine, have also had some little influence in the acceptance and development of the theory. But we must not forget that Hutton, though he could not prove it by figures, had as clear a conception of the fundamental truths of denudation as any that have come after him; and here lies his great merit entitling him to be considered, in my opinion, the father of physical geology as now understood. I trust the preceding remarks have indicated, if but feebly, the value of figures in their bearing on the demonstration of geological truths; and I venture to say that no one can possess a competent knowledge of the forces which have fashioned our earth until he has realized in his mind, by numerical investigations, the proportions of the matter to be dealt with. There has been of late much crude speculation on the distribution of land and sea, the origin of continents, the permanence of oceans, &c., which, if the writers possessed an accurate knowledge of the geometry of the earth and ocean, we might have been spared.

Thus we have oceans deepened or shallowed at the will of the theorizer, without any attempt to follow out the consequences. It seems to escape these philosophers that the volume of water on the globe is a constant quantity, that if the oceans become deeper, the land must increase in area, and if they become shallower the continents become submerged. In happy unconsciousness of these elementary truths they toil and spin to explain some particular facts that have made an impression on their minds. I need hardly add that

unless the theorist grasps all the consequences of his hypothetical re-arrangements of land and water, they possess but little value.

DENUDATION OF THE TWO AMERICAS.

My former calculations dealt almost exclusively with the amount of matter annually removed in river water from the surface of England and Wales, and from some of the river basins of Europe. I now propose laying before you calculations of a similar nature relating to some of the larger rivers of the two Americas. This done we shall be able to take a wider survey of the subject, and to ascertain how the provisional generalizations previous investigations led to are confirmed or otherwise by the greater experience since gained.

THE MISSISSIPPI.

First then we will see what the Father of Waters, the Mississippi, tells us. I may observe that for a long while I found him very reserved and disinclined to answer to my questionings. Years elapsed, and letters innumerable were written before I could alight upon any analysis of the waters of the Mississippi, reliable or otherwise. At last, through the kindness of Prof. J. W. Spencer, of the State University of Missouri, I was supplied with the following analysis:—

ANALYSIS OF MISSISSIPPI WATER, NEAR CARROLTON, A FEW MILES ABOVE NEW ORLEANS.*

IN A GALLON (56,000 GRAINS).

	GRAINS
Potash sulphate... ,, chloride ... Calcium chloride .	3·154

*Avequin (Journ. Pharm [3] XXXII. p. 258, 1857).

Silicic acid	2·455
Alumina	1·753
Calcium carbonate / Magnesium .... }	7·307
Organic matter................................	0·818
Total solid residue......	15·487

According to this analysis the proportion of total solids in solution is by weight $\frac{1}{3815}$. If we take the mean annual discharge of the Mississippi at 541,666,666,666 tons,* in round figures there are 150 million tons of solids in solution per annum poured into the Gulf of Mexico by the Mississippi—a truly remarkable quantity, which if reduced to rock at 15 feet to the ton, is represented in round numbers by 80 square miles 1 foot thick. According to Messrs. Humphreys and Abbot, the proportion of sedimentary matter to the water by weight is $\frac{1}{1500}$, and the total discharge of matters in suspension, excluding the three outlet bayous, is, according to them, 362,723,214 tons.†

The amount of matters in solution varies within certain limits in river water, according to the time the samples are taken. There are in some rivers—the Nile, for instance—seasonal variations; and doubtless a river with many affluents traversing strata of various degrees of solubility must vary in the chemical composition of its waters according as the flood may come from one or the other tributary basin. The last analysis would make the total solids in solution exactly $\frac{1}{3}$ of those in suspension, and it is a remarkable fact that this is the proportion that holds good with the Danube and the Nile, as I have before pointed out.‡

* Report of Humphreys and Abbot (1876) p. 146—19,500,000,000,000 cubic feet, at 36 feet to the ton.

† 812,500,000,000 lbs. ‡ "Rivers."—Trans. L'pool Geo. Assoc., 1882.

If we take the drainage area of the Mississippi proper at 1,244,000 square miles, the calculated amount of solids in solution, according to the analysis, will be 120 tons removed from each square mile of surface per annum. From the surface of England and Wales I have shown that 143·5 tons per annum are removed in solution,* and from the Danube basin 90 tons, so this is a mean, and probably correct.

It has been estimated that the basin of the Mississippi is lowered at the rate of one foot in 6,000 years,† but this rate has been calculated from the removal of sediment alone;‡ if we add to the matter removed mechanically that in solution, it will raise the rate to one foot in 4,500 years.§ What stronger evidence can we have of the importance of chemical action in geological investigation—an importance that has hitherto been strangely overlooked?

Not less surprising, considering the apparent insolubility of silica by ordinary agencies,‖ is the fact that in round numbers from 23 to 24 millions of tons of silica are poured into the sea annually by this river, while there

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* "Chemical Denudation," p. 20.

† Geikie, "Text Book of Geology," p. 444.

‡ According to the figures I have taken it would be one foot in 6,375 years.

§ This is estimated as follows:—Drainage area 1.244,000 square miles; annual sedimentary discharge from the same area 362,723,214 tons, solids in solution 150,000,000 tons; the average rock is estimated at 15 feet to the ton. Strictly speaking, to this should be added 750,000,000 cubic feet of matter, estimated to be pushed along the bottom and the discharge from the bayous. For simplicity's sake I omit these elements.

‖ Mr. M. E. Wadsworth has shown that ordinary atmospheric agencies produce a greater effect upon rocks of a siliceous character than is generally believed.—See *American Journal of Science*, December, 1884, p. 466.

are 70 million tons of carbonate of lime and magnesia.

There is also an exceptional quantity of alumina, and a low percentage of sulphates in this water.

THE RIVER PLATE, OR RIO DE LA PLATA.

The next river I shall deal with is the Rio de la Plata, the second greatest river of the South American Continent. I am indebted to the very exhaustive series of observations and analyses of the waters of this river contained in the report to the Commission of running waters of the City of Buenos Ayres, by Juan J. J. Kyle, in 1872 and 1874, for most of the information relating to this river. I must here express my thanks to Mr J. E. Hawkes for his valuable assistance in translating the pamphlet for me.

I find that the mean of 14 analyses of water taken at different times (April, May, and June) in the neighbourhood of and above the city of Buenos Ayres, gives a proportion $\frac{1}{6443}$ of solids in solution, which, taking the dry weather flow of the La Plata at 670,000 cubic feet per second * (Bateman), will equal 2·8886 tons per second, or 91 million tons per annum in round figures. The *dry* weather flow of the La Plata, equals the *mean* annual flow of the Mississippi. The mean annual flow of the La Plata is not known, but it must be greatly in excess of the dry weather flow, and sufficient to bring up the total amount of dissolved matter to above that of the Mississippi, though it appears from the analyses to have a less per centage in its waters than has the Mississippi. It appears from the report of 1874, that in two analyses of the La Plata water on September 15th and 18th, the matter in solution reached a proportion of $\frac{1}{3125}$. According to

* See "Chemical Denudation," p. 55.

an analysis of the waters of the Parana supplied me by Dr. Frankland,* they contained a proportion of only $\frac{1}{9926}$ of solids in solution. Mr. Juan Kyle states that there is very little difference between the waters of the La Plata taken at 850 m. from the shore, and the waters of the Paranâ de los Palmas. As the Parana supplied, according to careful measurement by Mr. Bateman, 520,000 cubic feet of water per second to the La Plata, while the Uruguay was estimated at only 150,000 cubic feet at the same time, it follows that the chemical constituents of the water of the La Plata must vary considerably at different times and seasons. Probably the analysis on which I have made my calculations will represent a fair annual mean of the solids in solution.

The estimated drainage area of these two rivers is 1,250,000 square miles, so that were the mean annual discharge known it would probably turn out that the greater discharge of the La Plata would more than compensate for the smaller percentage of dissolved matter in its waters, and bring the chemical denudation per square mile of river basin up to or beyond that of the Mississippi.

The observations of Mr. Bateman were taken in the month of December, 1870, when the river was at its lowest state. "A continuous drought of six or seven months having diminished the ordinary sources of supply, and the periodical rise from the Andes not having commenced." It is difficult—nay impossible—to predict the mean delivery from the dry weather flow, but the mean flow of the Rhine is given by Beardmore as over twice, the Rhone at Avignon, nearly three times, and the Nile at Cairo, over seven times the ordinary summer flow.

* "Chemical Denudation," p. 23. 10·08 parts per 100,000.

The waters of the La Plata are distinguished by the fineness of the matter held in suspension; this consists, according to Mr. Kyle, principally of clay. This clay continues a long time in suspension, even after filtering. It will pass through the pores of the best filtering papers, the water preserving its turbidity even after months of repose. This is a feature, according to Mr. Kyle, which is common to all waters that are weakly alkaline. Several chemicals added to the water, will, however, precipitate the solid matter by making the muddy particles coagulate into larger compound particles. Chloride of calcium in the proportion of 1 to 5,000 parts will act in this manner. The analyses given by Mr. Kyle are after 48 hours' subsidence, so that the precipitated matter is included in the solids in solution. The matters in suspension, as is the case with other rivers, vary much according to the state of the river, and the water is more impure near the shore than at 850 m. distant.

It is pretty well known that an admixture of sea-water with turbid fresh water tends to hasten the precipitation of the solid matters,* but it is very probable, as will be seen before I conclude, that the extremely divided solid matter will be carried far and wide by oceanic currents before it can settle to the bottom.

The annual amount of solids in suspension in the La Plata waters has never to my knowledge been determined, or even approximately estimated.

THE ST. LAWRENCE.

The next river on the American continent of which we have any knowledge worth speaking of is the St.

* See "Precipitation of Clay in fresh and salt water" by D. Robértson, Trans. of Glas. Geo. Soc., Vol. iv. Part iii., page 257.

Lawrence. The elements for a calculation such as I wish to make are, however, unfortunately rather vague. Even the area of its basin is stated differently by different authors. According to Guyot* its basin—including, I presume, the area of its immense lakes—is two-fifths that of the Mississippi, while it is said to pour into the sea more than twice its volume. This must, however, be an error, for it would give 40 inches of rain run off the area per annum; whereas, according to the Rainfall Map of the World prepared by Loomis (American Journal of Science, Vol. xxv. p. 88, Jan., 1883), the whole basin lies in the area of rainfall of from 25 to 50 inches. If we were to take it at 20 inches run off the ground per annum, or half the stated delivery—that is, a volume equal to the Mississippi—after deducting the area of the great lakes, where denudation cannot act, the chemical denudation would still be enormously great.

The only analysis I have met with gives the proportion of solids in solution at $\frac{1}{6250}$,† so that the denudation would amount to at that rate over 200 tons per square mile per annum. The one thing probable, however, is that the matter removed in solution is more per square mile than from that of the Mississippi basin.‡ The matter removed to the sea in suspension must be comparatively small from the clearness of the water due to its passing through the great lakes.

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* "Physical Geography."

† 16·05 per 100,000 parts. Jahresbericht der Chemie, per Prof. Frankland.

‡ Through the kindness of Dr. Alfred Selwyn, Director of the Geological Survey of Canada, I have, since the above was written, been supplied with the following information obtained from the Montreal Harbour Commissioners' Engineer :—

"The discharge of the St. Lawrence River opposite Victoria Pier,

Montreal, varies from about 580,000 cubic feet per second at high water of 24 feet on the lower lock sill of the Lachine canal in the latter part of May, to 330,000 at low water of 17 feet on the sill in October."

Thus it would appear that the minimum flow at Montreal is somewhat less than the mean flow of the Mississippi. The difference between the maximum and minimum flow is probably less than that of any other great river on the globe, due, doubtless, to the enormous reservoirs, in the form of a group of the grandest lakes known, from which its supplies are drawn. As the St. Lawrence receives the waters of the Richelieu, the St. Maurice, the Saguenay, and many minor rivers below Montreal, the estimate of the discharge on which I have based the calculations is probably near the mark, and is a satisfactory proof of the accuracy of the reasoning adopted.

NOTE ON NIAGARA, &c.—The "English Cyclopædia," Article, Canada, says that the mass of water projected over the Falls of the Niagara per minute is 710,000 tons (= 426,000 cubic feet per second), but at what season is not stated. Stanford's "Compendium of Geography and Travel" gives it as 169,344,000 gallons per minute (= 756,000 tons); in the General Description of the North American Continent, &c., in page 356, Part II., at 701,250 tons. It also states that the River St. Lawrence is the largest in North America as to volume (p. 351). The "Popular Cyclopædia" says it discharges, it is computed, 100,000,000 tons of water each hour (= in round figures, 1,600,000 tons per minute)! while Reclus ("The Earth," Sec. I. p. 344) says the river above the cataract discharges on an average 1,300 to 1,400 cubic yards of water per second (= 63,000 tons per minute. The *Handbook and Official Catalogue*, Paris U. Exhibition, 1878, p. 14, says, "The calculated discharge from the upper lakes by the Niagara River is over twenty millions of cubic feet per minute" (= 555,555 tons per minute)—about half the discharge of the Mississippi. The statements of the areas of the basin are equally discrepant. According to the "Imperial Gazeteer" the area of the basin of the St. Lawrence is 297,600 square miles, of which 94,000 are covered with the water of the lakes alone. The "English Cyclopædia" says, "The whole basin of the St. Lawrence is calculated by Darby to contain 537,000 square miles, 149,000 of which is occupied by lakes and its estuary, and that the basin above Niagara is 250,000 square miles." Stanford's "North America" does not give the area of the St. Lawrence basin, but says that the Mackenzie and its tributaries is about 550,000 square miles, almost double that of the St. Lawrence basin.

THE AMAZONS.

The River Amazons is compared by Agassiz in its main features to the Mississippi, inasmuch as it lies in a Cretaceous basin*. I think, however, the analogy is a fanciful one. The valley of the Amazons is distinguished from other river valleys by its immense extent, the drainage basin being estimated by Humboldt at over 3 million square miles. The basin appears to have existed much in its present form before it became partially filled with the remarkable deposits of red sandstones and clays covering an immense area, which the river is now engaged in rapidly removing to the sea. The upland portions of the basin are largely composed of the granitic and crystalline rocks which are such a prominent feature in the Brazils. The sandstones and clays that have so large a development over the bottom of the basin appear to be Post-tertiary, and laid down by the river itself in more ancient times. There are, however, Tertiary rocks in a part of the basin†, possessing an estuarine character, in addition to Cretaceous rocks; while on the flanks of the Andes draining into the river are found both Cretaceous and Carboniferous rocks. The larger area of the basin appears however, to be occupied by crystalline rocks, and the Post-tertiary sandstones and clays; but a very large part of the basin seems never to have been geologically explored. The basin of the Amazons has also the peculiarity of being situated both to the north and south of the equator, and in an area of very heavy rainfall. The chart of mean

*Geological Sketches—Physical History of the Valley of the Amazons —p. 171.

† See "On the Tertiary deposits on the Solimoes and Javary Rivers in Brazil," by C. Barrington Brown, Q.J.G.S., 1879, also "Ancient River Deposits of the Amazons," ibid.

annual rainfall by Loomis, before referred to, puts it at from 50 to 75 inches for about $\frac{2}{3}$ of its area, the remainder near the Andes being over 75 inches. The volume of water discharged by the river has been estimated at from 2,700,000 to 3,510,000 cubic feet per second. Taking the mean this would give about 15 inches run off the ground, or 0·25 of the total rainfall if we take it at 60 inches, about the proportion that flows off the Mississippi basin. The mean rainfall of the Mississippi basin is estimated by Messrs. Humphreys & Abbot at 30.4 inches. Probably 60 inches would represent the mean rainfall of the Amazons basin. For the purposes of this calculation I take the mean discharge at 3,105,000 cubic feet per second, or 86,250 tons= 2,719,980,000,000 tons per annum*

Through the good offices of Mr. E. Edmondson, of Messrs. Gunston and Co., of this city, I have obtained a sample of the water of the Amazons, taken in mid-stream between the Narrows and Santarem, in June of this year. This sample I submitted to Dr. Percy F. Frankland for analysis, with the following result:—

Parts in 100,000.	
Silica	0·98
Iron and alumina	0·38
Carbonate of lime	2·75
Carbonate of magnesia	0·22

* Bates, "Naturalist on the Amazons," vol. i. p. 237, says:—Von Martius estimates the volume of water passing through the Straits of Obydos at 499,584 cubic feet per second. He arrives at this result by taking the depth in the middle at 60 fathoms, and at the sides 20 fathoms, the width being given as 1,738 yards. Suspecting some error—as the volume of the La Plata in dry weather exceeds this estimated volume of the Amazons, I have re-calculated the delivery from these elements and find that it cannot be less than 3,000,000 cubic feet per second, but may be more according to the form of the bottom. Our gratitude is due to those who give us the means of checking their results.

Sulphate of magnesia	0·37
Chlorate of potassium	0·23
Chloride of sodium	0·15
Sulphate of soda	0·13
Organic matter..............................	0·71
Total solids in solution ...	5·92

This gives a proportion of total solids in solution of $\frac{1}{16890}$ or = 5·1 tons per second.

The total delivery of matters in solution will amount according to these data to 160,833,600 tons per annum, or if we estimate the basin at three million square miles, to 50 tons per square mile per annum.

It will be observed that the total amount delivered to the sea of solids in solution is not much greater than that we arrived at for the Mississippi. This is a fact worth knowing, and due doubtless to the preponderance of gneissic rocks, sandstones, and clays of an insoluble character. It is also worth noting that the proportion of silica to the total matter in solution corresponds very closely with that of the Mississippi, amounting to 26,624,481 tons per annum.

It is also evident that the rocks and Pampean deposits* accupying the basin of the La Plata, are also of a more calcareous and soluble character than the Amazonian rocks.

Not less interesting is it that the carbonate of lime, roughly speaking, is one-half of the whole of the solids in solution.†

It follows from these data that the matter removed in suspension must bear an excessive proportion to that in solution as compared to other rivers. The deposits

* See "Geological Observations"—Darwin. Second edition, pp. 313-69.

† See "Chemical Denudation," p. 24.

forming the banks of the river are of a loose and friable nature, on which the river makes great inroads. The proportion of matter in suspension has never to my knowledge been estimated.

Bates, comparing the Pará and the main Amazons, says: "In the former the flow of the tide always creates a strong current upwards, whilst in the Amazons the turbid flow of the mighty stream overpowers all tides, and produces a constant downward current. The color of the water is different, that of the Pará being of a dingy orange brown, whilst the Amazons has an ochreous or yellowish clay in it." Also: "Indeed the fresh water tinges the sea along the shores of Guiana to a distance of nearly 200 miles from the mouth of the river." *

INFERENCES AND GENERALIZATIONS.

In my former address I said "Taking into consideration what we know of the geology of the world, I think we have sufficient grounds for a provisional assumption that about 100 tons of rocky matter is dissolved by rain per English square mile per annum." † This, at the time, was considered a very bold statement; but from the data I have laid before you respecting the American continents, I venture to think it will now be considered, as applied to the whole world, a very fair approximation.

Let us pause to consider the meaning of all these figures, for unless they have a meaning which the mind and imagination can seize upon, the wearisome labor of collecting the data and making the computations were well-nigh wasted.

First, as regards the Mississippi, of which we possess the most reliable particulars. I have shewn that the

* "Naturalist on the Amazons," vol. i., p. 5.

† "Chemical Denudation," p. 24.

estimate of the rate of denudation of its basin must be increased in round figuros from $\frac{1}{6000}$ to $\frac{1}{4500}$ of a foot per annum* in consequence of the solid matter which is removed in solution.

Is it not a striking instance of the little importance attached to chemical denudation as a geological agent, when the matter removed in solution does not enter as an element into the calculations of such observant reasoners as a Geikie or a Croll? Thus we arrive at the first and not unimportant result which I promised from quantitative examination. Now mark, it is not that geologists were unaware of the effect of chemical action on the rocks. Take up any text book or manual, and you will find a chapter devoted to it and the whole process correctly explained; nevertheless, the quantity of matter removed was not realized, and never could have been except through laborious calculations. That being done, it is easy to see how these great results occur. Examine the hardest rock, and you will find it weathered; you will find it coated over with a crust of a thickness varying with the time its surface has been exposed. This crust is composed of the constituents of the rock that remain after part have been removed by chemical action.† Examine the waste talus from some of the old quarries at Penmaenmawr and you will see that atmospheric agents have, in the space of 30 years, perceptibly

* This calculation, as before explained, takes no account of matter pushed along the bottom; its quantity has not been determined with much accuracy, and it is probable, as Mr. Tylor has suggested, there is more than has been estimated. This would further reduce the time.

† It is usual to refer this action to the carbonic acid present in the rain water, but Mr. Alexis A. Julien has brought forward a great body of facts to prove that the solvents of the rocks are largely organic acids existing in decaying vegetable matter.—"On the Geological action of the Humus Acids." Proc. of the American Assoc. for the Advancement of Science, Saratoga meeting, 1879.

affected a felstone rock that seems at first sight absolutely indestructible.* How much more then must they affect rocks of a more friable and soluble nature. I have shewn that $\frac{1}{12978}$ of a foot per annum is removed from the surface of England and Wales in a soluble form every year,† say $\frac{1}{1081}$ of an inch, so that in 30 years it would amount to $\frac{1}{36}$ of an inch. This is the *mean* denudation; but I have also shewn that the denudation is very much equalized, by the fact of the harder rocks usually occurring in areas of great rainfall.‡

It is therefore not unlikely that if we were to institute accurate experiments over a sufficiently long time, it would turn out that the calculation of the amount of matter removed in solution could be verified by direct tests, and that even these hard rocks would be found to waste at something near the indicated rate.

It would appear from the examples of the Mississippi, the Nile, and Danube, that the matter brought down in solution and in suspension is as 1 to 3. These examples are of rivers where there has been the most accurate and fullest data to judge by. Whether the proportion would be borne out in other river basins we have no very good means of judging; but it would appear that in large rivers the nature of the rocks is so varied, the areas being so extensive, that the relation of the materials in solution to those in suspension have a tendency to keep very constant. It will be seen from a consideration of these facts, that matters chemically dissolved in the water must play a much more important *rôle* in the re-construction of the earth than was

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* This stone is largely used for making "setts" for street paving, sold under the name of "Welsh granite setts," and found to be the most lasting material for the purpose.

† "Chemical Denudation." ‡ "Chemical Denudation."

formerly suspected.* What becomes of all these mineral matters ceaselessly flowing into the sea? It has been shewn by Mr. Buchanan † that the proportions of mineral substances to each other in sea water are nearly constant everywhere, although there is a variation in different seas in the proportion of total mineral matter in solution to the water it is dissolved in. Nature has achieved a balance of supply and demand. It is also well known that the coarser materials in suspension, unless brought under the influence of a strong current, settle near the mouths of the rivers, and then spread themselves, by help of tides and winds, along the coasts, and there mingle with the detritus the sea wears away from the coast. The finer particles distribute themselves over a larger area, and, probably, the very finest over the whole sea bottom. In every ocean dredging there is a greater or less amount of argillaceous matter—whether it be in the ooze or the Red Clay—which I suggest is more likely to be "the dust of continents" than to arise from the disintegration of volcanic matter such as pumice, but it is no doubt largely mingled with such volcanic materials, as Mr. Murray clearly shows. It seems to me rather a far-fetched notion that the winds should contribute dust to the deepest ocean, but that the waters should make no mechanical contribution to the deposit. The bulk of the ocean water is so great as compared to the probable amount of matter in a state of the finest comminution that can get into it, that it might not even be possible to

* It is singular that Hutton, in his "Theory of the Earth," estimates "at a gross computation," that one-fourth of the solid land is composed of matter which had formed the calcareous tests of animals.

† "Challenger Reports,"

detect the presence of substances in suspension in a sample of ocean water. At the same time the water might contain quite sufficient to account for much of the argillaceous matter found in the deep ocean soundings. I have shown that the matter in solution in river waters is, roughly speaking, one quarter of the whole matter in solution and suspension. The finest particles—sufficiently fine to be carried away by oceanic surface currents such as the Gulf Stream, are probably not in aggregate bulk half as much as the matter in solution. If we take as an example the estimate I have given of the chemical denudation of England and Wales, it will amount, as I have already shewn, to $\frac{1}{16}$ of an inch in 30 years. This would give, supposing the impalpable mud to be worn off at half that rate, 60 years for the denudation of $\frac{1}{16}$ of an inch. The area of the sea to land is roughly as 3 to 1, therefore at this rate it would take 180 years for $\frac{1}{16}$ of an inch of mud converted into rock to accumulate if distributed evenly over the ocean floor. When we consider that the average depth of the ocean is over 2 miles, $\frac{1}{16}$ of an inch distributed through it would amount to no more than about one five-millionth part, and this, be it remembered, has 180 years in which to accumulate and settle; so that if we give each particle of these fine substances in suspension 10 years to settle to the bottom, there would never be in the ocean water at any one time more than one ninety-millionth part of matter in suspension, an amount so small as to be practically imperceptible. The probability that such an infinitesimal amount of matter in suspension may be present is still more evident when we find that fine sand floats on the surface of the sea for considerable distances, for Prof. Verrill says that in the course of the Gulf Stream they always take with their towing

nets more or less fine siliceous sand* (Amer. Jour. of Science, 1882, xxiv., p. 449). I think it is fairly evident, from the foregoing calculations, that there may be accumulations going on in the great oceans which we can no more see than we can the matters in solution.† It is only because the mineral substances get concentrated in the sea water that they are forced upon our notice. They slowly concentrate until a balance is attained, when they are removed from the sea water at the same rate

* Prof. A. E. Verrill also says "that in the Gulf Stream slope examined by us, the bottom in 70 to 300 fathoms, 60 to 120 miles from the shore, is composed mainly of very fine sand, largely quartz, with grains of felspar, mica, magnetite, &c.; with it there is always a considerable percentage of shells, of foraminifera, and other calcareous organisms, and also spherical, rod-like and stellate sand-covered rhizopods, often in large quantities. In the deeper localities there is usually more or less genuine mud or clay, but this is often almost entirely absent, even in 300 to 500 fathoms. The sand, however is often so fine as to resemble mud, and is frequently so reported when the preliminary soundings are made and recorded." "The prevalence of fine sand along the Gulf Stream slope in this region, and the remarkable absence of actual mud or clay deposits, indicate that there is here, at the bottom, sufficient current to prevent, for the most part, the deposition of fine argillaceous sediments over the upper portion of the slope in 65 to 150 fathoms. Such materials are probably carried along till they eventually sink into the greater depths nearer the base of the slope, or beyond, in the ocean basin itself, where the currents are less active."—*Amer. Jour. of Science*, 1882, vol. xxiv., pp. 448-9.

† Mr. Thomas Higgin, F.L.S., of Anderton Salt Works, Northwich, prepares his finest quality of salt by precipitating the slight proportion of muddy impurities which the cold brine holds in suspension, by heating it to a temperature of 107° Fahr. in large vats. At my suggestion he carried out a series of experiments to determine the proportion of mud so removed. He found that it amounted to 57 lbs. per 1,556 tons of brine $= \frac{1}{61148}$. Looking at the brine purified and unpurified together, in clean bottles, the difference between them is so faint as to be hardly distinguishable. It of course affects the colour of the manufactured salt to a much greater extent, both by the higher proportion the impurities bear to the salt, and the whiteness of the salt.

that they are poured into it. How are the millions and millions of tons annually supplied by the land to the sea ultimately disposed of? But let us first make a rough approximation to the amount of matter in solution annually poured into the Atlantic.

EFFECT OF SUBSTANCES IN SOLUTION ON THE ATLANTIC OCEAN.

The basin of the Atlantic it has been estimated contains in Europe three millions of square miles, nearly half a million in Asia, and about six millions in Africa, not less than six millions in South America, and more than six millions of square miles in North America, in all about 21 millions of square miles.*

If we estimate this area as yielding 100 tons per square mile per annum, which I have shewn is a moderate computation † further verified by the remarkable fact that the mean of the four great American rivers I have given amounts almost exactly to 100 tons per square mile, the total amount of mineral matter poured into the Atlantic in solution every year amounts to 2,100 million tons per annum. We may represent this astounding result in a way to be readily realized by roughly placing it as rock at half a cubic yard to the ton or equal to a specific gravity of 2·67, in which case the deposit would cover 1,016 square miles one foot thick annually; or, to put it in another way, in less than six years one cubic mile of solid rock of a specific gravity of 2·67 is dissolved and carried into the ocean by the rivers draining the Atlantic basin.

How is this enormous amount of dissolved mineral matter disposed of? It has been said, I think more from a keen desire to establish a pet hypothesis than from

* "English Cyclopædia," article, Atlantic Ocean.

† "Chemical Denudation," p. 24.

any basis of fact, that the greater part of the carbonate of lime is used up in the formation of coral reefs, or on the shore by molluscs. It is indeed extraordinary in face of the vast areas of calcareous ooze discovered by the Porcupine and Challenger soundings, that such a contention should be seriously maintained. A little consideration will shew, however, that one foot of calcareous matter distributed over an area of the Atlantic Ocean, equal to the land from which it is derived, viz.: 21 millions of square miles, would equal in round numbers, 4,000 cubic miles. Now this amount of matter is directly supplied by the rivers to the sea, in the form of carbonate of lime, at the rate of 50 tons per square mile, per annum, in about 38,000 years.* Are there 4,000 cubic miles of coral reefs in the Atlantic? Is it not preposterous to contend that nearly all this enormous amount of calcareous matter is used up on the shores, when we have direct evidence to the contrary.† But if we were to grant that the lime is disposed of on the littoral zone, what becomes of the remainder of the mineral substances?—of the 20 million tons of silica, for instance, that I have shewn is poured into the Gulf of Mexico by the Mississippi alone? Is this all used up on the shore, and does none get out into the deep ocean?

If then, as these calculations clearly shew, a large

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* See "Chemical Denudation," p. 37.

† A large part of the coral deposits in the Pacific Ocean is being formed on and around islands, which are all assumed by Mr. Wallace to be volcanic, and where there has never according to him been continental land. How can corals in such a position help to build up continents that have remained permanently elsewhere, *i.e.* in their present positions. If not, the carbonate of lime of which the islands are composed, must on his favorite hypothesis be as entirely lost to the land as if it had been deposited as globigerinæ ooze at the bottom of an abysmal ocean from the dawn of creation.

part (the largest part, as I believe) is used up by pelagic organisms and finds its way to the ocean bottoms—the whole central bank of the Atlantic is covered with the tests of these animals—it will be quite evident on a little consideration that the constitution of the rocks of the globe would be undergoing a gradual alteration, had nature no means of redistributing these oceanic deposits; and the only means we are acquainted with is by upheaval into land and redistribution by denudation.

It is a self-evident proposition that if a large portion of the carbonate of lime of the lands of the globe is being annually abstracted from them and deposited in the abysses of the ocean, from which it is never recovered, the total amount of lime in the rocks that compose the land must have been diminishing from the dawn of geological time.* But we find this is not so, for the rivers draining basins in which the younger rocks predominate bring down more lime in solution than do those from palæozoic areas.

I trust I have now made it pretty plain that measurement and proportion are things not to be neglected in Geology; but hitherto they have been, comparatively speaking. Vague and loose theories are given to the world which, if tested in the way I have pointed out, quickly fall to pieces. The method of treating great problems is often excessively crude and imaginative, founded on mere analogy, than which nothing is more often misleading. Much of the weak theory not seldom incorporated with present day geology would vanish if juster conceptions of the proportions and relative magnitude of the things treated of were general. It would almost seem as if some theorisers entertained the idea that the lesser *may* include the greater.

* "Chemical Denudation," p. 49.

Further Examples of the Bearing of Measurement and Proportion on Geological Problems.

This address was commenced with certain calculations relating to the amount of matter removed in solution by river water; but we have been led up by it to a consideration of the value of measurement and proportion in Geology generally, and the light that it helps to throw upon some complicated but nevertheless interesting problems.

Let us, as a further example, analyze the theory lately adopted by some scientific men, that the oceanic and continental areas are permanent and uninterchangeable. But first it is worth while pointing out that there is not one argument—at all events one that I can call to mind—which has been used in its favor that is not directly or indirectly based on negative evidence, the most unscientific of all evidence, from the difficulty, nay, often impossibility, of adequate proof. Thus it is said there are no deposits among the rocks equivalent to the deep sea oozes and red clays; there are no oceanic islands but what are volcanic; there are no indigenous land-mammals on oceanic islands. In this way is built up a tremendous theory which is to supersede all the older geological notions. It seems to be overlooked while framing these all-embracing propositions, that what is known of the ocean has been obtained by the most superficial scraping of the bottom, at a very few points enormous distances apart, and a few soundings that bear an infinitesimal proportion to the extent of the ocean, yet which are supposed to give accurate indications of the form of the bottom.

Let us now for a moment look at the problem from the point of view of the geologist who takes the trouble to measure and balance before pronouncing an opinion. Firstly, if we except granitic and igneous areas, there is

no known place on any land on a coast line where stratified rocks of earlier or later date do not exist; or where if they do not appear on the surface, the oldest rocks are not met with when a bore-hole is put down sufficiently deep. In a word, the framework of continental land at the coasts differs in no respects from the inland areas.

If land areas have been, as contended, permanent, the stratified rocks of which they are composed must have a beginning and ending somewhere—what engineers would call a "limit of deviation" must have been marked out for them somewhere,—where does this limit exist? Surely, at the present time, this limit should, at some point or other, be near the coast; if so, where is the evidence of such, a thinning out and shading off? I hope I make my meaning sufficiently plain; the stratified deposits—I speak of the older rocks, not the modern littoral deposits—must, if the theory be true, thin off from the continents somewhere. If at only one small place this could be pointed out, we should have some basis of fact to go upon. Dana says that the Laurentian rocks everywhere underlie the land areas. Considering that fluctuations of the limits of continents have to be allowed for on any theory, this shews that, as notwithstanding these oscillations we are not anywhere on the edge of the stratified rocks laid down untold millions of years ago, they must have a very extensive development under the sea bed. Let us pause to consider what is taking place now. The Atlantic Ocean, as I have shewn receives the waste of 21 millions of square miles of land forming its basin.

The greatest continental rivers—the Amazons, the La Plata, the Orinoco, the Congo, deliver their waters directly into the Ocean. The Mississippi debouches into the Gulf

of Mexico, the St. Lawrence deposits are largely intercepted by the great lakes; but by far the larger areas of the surface of the two Americas are so canted that either directly or intermediately the deposits are carried into the Atlantic Ocean. How long this has been going on I will not now stop to enquire, but in the course of time, unless some change takes place, the land will be worn down to the sea level, and the continents become lagoons. Or if on the other hand the land were to keep on rising, the whole of the stratified rocks would be worn down to the fundamental rock of the globe—whatever that may be—an event that has never yet to our knowledge occurred in the geological history of the earth. Now assuming for the sake of explaining my meaning that the river deposits are confined to a strip of land extending 200 miles from the coast (which I hesitate to admit) if the denudation of the 21 million square miles of land were to keep on its present lines the result would be a shoaling of the present deep water, and a pushing seaward of the littoral deposits. This would not cease so long as the rivers continued to bring down any matter to deposit.

But if the world is to last on the old lines—if its geological history is to continue as hitherto—a time must eventually come when these deposits will be uplifted and made into land. It is pretty well agreed among all geologists now that such an upheaval is an extremely slow process, and it is not improbable that the rivers would continue in their present courses, and cut through the deposits as they arose.* This would push out the detritus still further, and lay it down on the flanks of the upland chain of mountains, if such there were. It is

* Captain Dutton shows plainly that this has taken place on the West of the Rocky Mountains.—Tertiary History of the Grand Cañon District.

easy to see that in time the deposits would travel round the globe, for if we assume that eventually the continents get a cant in a direction opposite to what obtains now, the same process would be repeated on the opposite coasts. No amount of catch pits in the shape of inland seas, that either nature or human ingenuity could devise would suffice to stop this travel of material.

When we consider that the very oldest rocks everywhere underlie the land, that they reappear in islands which it is the fashion now to speak of on that account as non-oceanic, but which lie at considerable distances from the great land areas, and so sketch out in positive evidence their *least* extent at those early times. When we consider that the island of South Georgia, separated by 1,200 miles of ocean from South America, is composed of clay slate, and has an Alpine character* and high mountains, it will seem incredible that the waste of the land could in any way be confined to the limited areas which the hypothesis of the permanence of oceans and continents demands. At all events, I think that those who hold the theory should have some consistent way of explaining its *modus operandi,* instead of confining themselves to vague generalities or making phrases do duty for ideas. What I should like to see explained is this:—Where do the rocky formations we see on the land thin out and end seawards? and by what process during the fluctuations of the land have the deposits been kept from getting outside the areas the theory requires them to be laid down in? In fact, what sort of a basin is it over which a particle of detritus can never travel? But let us see if figures will aid our conception of the problem.

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* See "Island of South Georgia," *Geological Magazine*, Dec. 3, vol. i., No. 5, 1884.

The area of land draining into the Atlantic, as I said before, has been estimated at 21 million square miles. If we assume the denudation of all sorts over this surface to equal one foot in 3,000 years,* that will amount to one mile in 15,840,000 years, say 16 million years.

The area of the South Atlantic, from the equator to the 40th parallel, is, I have ascertained by careful measurement on the map, 10,239,600 square miles, say ten million square miles.

The area of the North Atlantic, from the equator to the 40th parallel, is in round numbers 11 million square miles; that is, the area of the Atlantic from the 40th parallel of latitude north, to the 40th parallel south, contains an area approximately equal to the area of the land draining into both the North and South Atlantic. I doubt very much whether the mean depth of this part of the ocean equals two miles; but, for the sake of calculation, let us say two miles. It follows that in 32 million years the detritus of 21 million square miles of land, at 1 foot in 3,000 years, would fill up and level the whole of this vast basin. But let us take a more restricted area. The river Amazons and the Congo, the two largest rivers in the world as regards water volume, deliver their floods into the Atlantic Ocean from opposite continents, and nearly at the equator. The combined area of their basins is probably not short of 4½ millions of square miles. The area of the Atlantic below the parallels 10° N. and 10° S. is 4,800,000 square miles. The whole of this vast cavity, taking into consideration the enormous volume of their waters, which means an increased rate of denudation, would probably be levelled up by these two rivers alone in 20 million years. These

*I take these figures because they have been used by others, and are near enough for my purpose.

two great rivers deliver their waters into the ocean direct; yet, in the face of this fact, we are told by some geologists that most of the deposits we are geologically acquainted with have been laid down in inland seas! Now I ask this simple question,—by what possible arrangement of inland basins, gulfs, or lakes could this vast degradation of the land be kept within the limits necessary to avoid the land absorbing or taking the place of the ocean? If the rate of denudation were greater in earlier ages of the earth's history, as some assume, this only makes the *time* less, and our difficulties greater! Now mark further, for this is of special importance. The Red clay deposits which are responsible for much of the latter-day theorising, and which are supposed to prove that the ocean bottom has never been upheaved, are carefully mapped out in Mr. Murray's map. I have transferred them to the "Geological Map of the World," by Jules Marcou, a map to which I have been much indebted in investigating these problems. You will observe that they approach within from 300 to 400 miles of Rio Janeiro, and the same from the Cape of Good Hope, while they come close up to the West Indian Islands at Porto Rico, and to the Leeward and Windward Islands, which connect the West Indies with South America, and, which all admit, were once joined to it. It follows, therefore, on the hypothesis of "permanence," that though the continent of South America was in existence, and extended at least as far eastward as at present, at an early geological age—as proved by the crystalline rocks of the Brazils—that either the deposits, through all the geological time that has since elapsed, have been unable to travel out over a space of from 50 to 400 miles, so as to shallow the sea and cover up the deep sea deposits, or that what

is now deep sea was formerly shallow sea, so that the Red clay is precipitated on preceding deposits of another nature. The first alternative is too absurd for acceptation by anyone who has accurate perceptions of geological time—or even any conceptions at all—and the latter disproves the supposition that the presence of Red clays is in any way a proof of the *permanence* of oceanic areas. The existence of profound depths of the ocean within a comparatively short distance of the land is fatal to the supposition that the land areas have been in their present positions through all geological time. They point rather to vast changes of relative level having taken place in the crust of the Earth during geological time—under the ocean as well as on the land. The same argument will apply to the Cape of Good Hope, for there the oldest crystalline rocks also exist. It has also been proved by the soundings of the U. S. Fish Commission Steamer "Albatross," that in N. lat. 37° 12′ 20″ W. long. 69° 39′ or some 300 miles S.E. of Cape Cod, that the bottom is no less than 2,949 fathoms, or over 3½ miles deep. The bottom in all soundings below 1,000 fathoms was found to be "mainly composed of Globegerinæ ooze, usually having the consistency of fine sticky mud, commonly of a dull olive-green or blueish color. When washed with a fine sieve the deposit is found to be mixed with a considerable amount of very fine siliceous sand, among which are some grains of magnetite and garnet." It will be interesting also to those who speak so confidently of the depth of ancient oceans to know that a "considerable number of our shallow water species have been found to have a much greater range in depth than was anticipated, many of them going down below 500 fathoms, while some even go below 1,000 fathoms.*

* A. E. Verrill, Amer. Jour. of Science, 1884, pp. 213-14.

If we consider that the island of South Georgia, situated on the same parallel as Cape Horn, the southernmost part of South America, is separated from it by 1,200 miles of ocean* and is composed of clay slate, we cannot help seeing how absurd such ideas seem when put to the test of facts and figures. It has been thought by some that if it could be found that the island of South Georgia were once united to South America the difficulty of its existence would be got over; but it is plain that, so far from proving the hypothesis of the permanence of oceans and land areas, such a former connection points to the opposite conclusion.

I trust I have now shown what an intimate relation exists between a correct conception of the magnitudes of the various parts of the earth, the rate of denuding agencies and of geological time, and the great and interesting geological problems which we strive to understand.

This knowledge is only to be obtained by constantly reducing our otherwise vague ideas to figures, so that we can realize, handle, and weigh the various parts we attempt to reason about. This is the more necessary as the ordinary means adopted of conveying the information is the source of most people's difficulties. Vertical dimensions are exaggerated, and maps of the globe necessarily distort the parts. Even those who know this are nevertheless affected by the conventional method of representation adopted in cartography, and the only way to throw off this influence and realize the value of figures is to work them out oneself. This may seem humble work, but geology has now arrived at a stage in which for its further advancement scientific precision is required.

* Island of South Georgia. Geo. Mag.

THE PRESENCE OF CALCAREOUS SPICULA IN THE TUNICATA.

By W. A. Herdman, D.Sc., F.R.S.E.,

Professor of Natural History in University College, Liverpool.

Since the fossils known as Cystideans have been referred to their proper position amongst animals, it has generally been admitted that there are no Tunicata known in a fossil condition ; and it is, I believe, generally supposed by Palæontologists that Ascidians are entirely soft-bodied animals, which have no parts capable of being preserved as fossils. This, however, is far from being the case, and I make the present communication for the purpose of drawing the attention of Geologists to the fact that in several groups of the Tunicata calcareous spicules exist in great abundance, and in all probability have as good a chance of leaving traces in the rocks as the similar spicules of Sponges, Alcyonarians, and Holothurians.

In one group of the Compound Ascidians, namely, the family Didemnidæ, it has been long known to Zoologists that calcareous spicules of a spherical or stellate form are present in great abundance. These spicules are of fair size—on an average about 0·04 mm. in diameter, and they exist in such quantities in some species as to convert the colony almost into a solid mass of calcareous matter. They were first described by Savigny in 1816,

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* Mémoires sur les animaux sans vertèbres, pt. II. fasc. i. Paris.

and have since been figured by Milne Edwards,* Giard,† Kölliker,‡ and others.

It has recently been shown by Dr. R. von Drasche § that a second family of the Compound Ascidians—the Distomidæ—contains some species which have spicules. For these forms, von Drasche founded the genus *Cystodites*, containing two species, and during the last few weeks I have found, in the collection of Tunicata formed during the Challenger expedition, two additional species which also contain spicules, and are referable to the same genus. The spicules in *Cystodites* are very remarkable. They take the form of discs of very considerable size (about 0·5 mm. in diameter), which are closely placed around the bodies of the various members of the colony. The discs are sometimes flat, sometimes thicker in the centre than at the periphery, and sometimes a little curved. They are always marked on their surfaces by numerous radiating lines, and usually by a few concentric rings.

Turning now to the Simple Ascidians, we find that, although calcareous spicules are present in some forms, they are not so abundant as in the Compound Ascidians, and they are not confined to the test as they are in that group. Heller ‖ was, I believe, the first to describe spicules in a Simple Ascidian. In 1878, he briefly stated

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* Observations sur les Ascidies Composées des Côtes de la Manche. Paris, Mém. Acad. Sci., t. xviii., 1842.

† Recherches sur les Ascidies Composées ou Synascidies. Archiv. Zool. expér. t. I., 1872.

‡ De la Compos. et de la Struct. d. enveloppes des Tuniciers. Ann. d. Sc. Nat., ser. iii. (Zool.), t.v., 1845.

§ Die Synascidien der Bucht von Rovigno. Ein Beitrag zur Fauna der Adria. Wien, 1883.

‖ Beiträge zur nähern kenntniss der Tunicaten. Sitzb. d. k. Akad. d. Wissensch. Bd. lxxvii., i. Abth., 1878.

in a description of the new species *Cynthia pallida* from Mauritius, Jamaica, and Tahiti, that calcareous spicules were present in the test. A few years later I was able to confirm his discovery by an examination of some specimens of this species in the Challenger collection, and I also found similar spicules present in several other species of the Cynthinæ, * and Sluiter has since extended the discovery to other closely allied forms. These spicules are all of more or less elongated fusiform shapes, and are covered by rows of fine projections or spines. I found them present not merely in the test, but also in the mantle, the branchial sac, the tentacles, and other parts of the animal.

A second group of Simple Ascidians, the Bolteninæ, also contains calcareous spicules: this I discovered in 1880, † when examining the specimens of the remarkable deep-sea genus *Culeolus* brought home by the Challenger expedition. The spicules in these forms are quite unlike any other spicules which I know of. Figures of them are given in the report upon the Challenger Tunicata, part 1., published in 1882; they are branched and often of large size, their ends are never sharp, and their angles are rounded, while their surfaces are marked by a series of very delicate contour lines.

Quite recently von Drasche‡ has found that a large Ascidian which is apparently rather common in the New Zealand seas, viz., *Boltenia pachydermatina*, contains in its thick cartilaginous test numbers of minute knobbed rod-like calcareous spicules very like

* "Challenger Geological Reports," vol. vi., part xvi., p. 145.

† Preliminary Report upon the Challenger Tunicata, part iii., Proc. Roy. Soc. Edin., 1880-81, p. 82.

‡ Ueber einige neue und weniger gekannte aussereuropaische einfache Ascidien. Denksch. d. k. Akad. d. Wiss. Wien, Bd. xlviii, Abth. 2.

those of some of the Alcyonaria, and I am able, from the examination of some specimens now in my possession, to corroborate his statement.

The present position of the matter then, is that in two groups of Compound Ascidians—the Didemnidæ and the Distomidæ,—and in two groups of Simple Ascidians—the Cynthinæ and the Bolteninæ,—calcareous spicules are present in great abundance. Of these four sets of Ascidians, one, the Bolteninæ, is mainly confined to very deep water, the abyssal zone; while the other three are shallow water groups occurring round coasts. Many of the spicule-bearing species of the Didemnidæ are very common in our own seas.

In conclusion I may state that from embryological and phylogenetic considerations there is reason to regard the Tunicata as a very ancient group; but, on the other hand, those Ascidians in which spicules are present are by no means primitive forms. The Cynthinæ and the Bolteninæ are Simple Ascidians of fairly high differentiation, while the Distomidæ and the Didemnidæ are neither of them closely related to the ancestral Compound Ascidians, and consequently may have been evolved in comparatively recent times. Still, it would be well to bear in mind when fossil spicula are being critically examined, that such structures may possibly indicate the presence of Tunicata.

THE CONSERVATIVE ACTION OF ANIMALS IN RELATION TO DYNAMICAL GEOLOGY.

By W. A. Herdman, D.Sc., F.R.S.E.,

Professor of Natural History in University College, Liverpool.

The influence of some animals in preserving rocks from epigene or surface action, seems to me a point which has been too much neglected by Geologists when discussing the operation of surface agents. Professor Archibald Geikie, in his admirable "Text Book of Geology," where the processes placed under the head of Dynamical Geology are all duly recorded, classified, and treated with great fulness, comes to the conclusion, in discussing the influence of life on epigene action, that "animals do not exert any important conservative action upon the earth's surface, save in so far as they form new deposits." He then mentions some minor effects produced in the prairie regions of North America by herds of roving animals, such as the bison and the elk.* No reference is made to the protection which marine animals, as I shall presently show, afford to a coast line; although in the previous section, on the conservative action of plants, attention is drawn to the influence of Nullipores, and of other Algæ, in breaking the force of waves and otherwise retarding the erosion of the rocks.

I have been much struck during the last few years, while investigating the marine zoology on various parts of the coast, at the comparatively large extent of surface of the rocks and stones of the beach which is covered by encrusting or adhering animals, and it has several times occurred to me that these protecting animals must

* "Geikie's Text Book of Geology," p. 457, Macmillan, 1882.

necessarily have a very considerable influence upon the rate and extent of marine erosion. I shall describe a few of the more important cases which have come under my notice with the object of recording which groups of animals are concerned, and of bringing the matter before the attention of Geologists.

On some coasts by far the most abundant organism in the littoral zone is the common acorn-shell (*Balanus balanoides*), one of the Cirripedia. This Crustacean, after a free-swimming larval existence, adheres to the surface of a rock, or some other object, and proceeds to form around itself a very solid calcareous case which is secured so firmly to the rock that it is usually impossible, even with a chisel and hammer, to detach one unbroken. On many rocky shores I have seen the *Balani* so closely packed side by side that for a considerable distance no portion of the rock was exposed. They form a continuous layer covering the surface, and in some places more than one row deep, young *Balani* having attached themselves to the tops of the shells of older and usually dead individuals. In some parts of the Frith of Forth where there are steep sea-cliffs with little or no seaweed attached, the *Balani* extend up nearly to high-water mark, and as seen from a boat when the tide is out present the appearance of a conspicuous white band on the cliffs extending upwards from the sea and ending in a regular horizontal line. It is obvious that this thick and hard calcareous covering must entirely protect the rock from abrasion due to currents, waves, tides, and the grinding action of sand and mud; while it will at least greatly mitigate the bombardment caused by breakers hurling bolders and shingle against the cliffs. It will also, in some cases, by filling up the fissures and joints, prevent the entrance of portions of

waves, which tend to force asunder masses of the rock.*

In considerable contrast to the hard and rigid form of protection afforded by the *Balani* is the soft and in some cases almost gelatinous covering produced on some parts of the coast by such animals as Sponges and Compound Ascidians. Colonies of these may be found in some favoured localities covering the rocks near low-water mark for many square inches, and occasionally even for several square feet, without a break. They adhere so closely to the surface that neither air nor sea water can gain access to the piece of rock they cover. These organisms do not as a rule extend so far up the beach as the *Balani*; but in their own zone, which extends from a little below to a little above low-water mark, they are usually very abundant.

At the southern end of Lamlash Bay, Arran, there is a bit of beach one hundred or a hundred and fifty yards in length, formed entirely of more or less angular fragments of stone, each averaging perhaps a foot square by six inches thick. These stones have Algæ (mainly *Fucus* and *Laminaria*) attached to their upper surfaces; while beneath, near low-water mark, they are covered by large colonies of Sponges, Compound Ascidians, and such Polyzoa as *Lepralia*, *Membranipora*, and other allied forms. There is a similar shore of much greater extent on the eastern coast of Mull to the south of Salen, where the stones are also greatly protected by soft adhering colonies. In such cases—and they are probably very numerous, as it is a common form of shore—I believe that the wearing down of the stones and their conversion into shingle and gravel must be very greatly retarded by the encrusting layer of gelatinous animals.

* See Geikie, loc. cit., p. 428.

On some of the islands of the Chausey Archipelago, off the coast of France, I found a few years ago granite boulders entirely or partially covered by a layer of closely-placed Simple Ascidians, and small caves about low-water mark were found to be lined by a red mammillated stratum which, on close examination, proved to be formed of immense numbers of a small Simple Ascidian, so closely placed as to completely conceal the rock. Similar cases are to be seen on the small island of Inch Kenneth, off the west coast of Mull; where, however, Sponges and Sea-anemones contribute to the formation of the encrusting layer. In all such cases the rock must be greatly protected by the animals.

Such protection will of course be of more value to some rocks than to others. And I believe that the nature of the rock has a good deal to say to the kinds and quantities of animals adhering to it. This is a subject which still requires to be worked up; but a good deal of my experience goes to show that some kinds of rock are better fitted than others to support a large and varied fauna. We see this difference clearly marked in the case of a stony shore where several kinds of rock are present. For example, far more animals will be found attached to the granite boulders than to the lumps of basalt or of sandstone. By the action of this selection on the part of adhering animals, certain rocks and certain shores may be somewhat more protected from marine erosion than others.

On the sandy coast to the north of Granville, in Normandy, I was interested to find that a species of Annelid (*Sabellaria*, sp.), had formed a sort of coarsely porous rock, by making from the sand innumerable closely-placed tubes. The tubes seemed to be formed merely of agglutinated sand grains, and occurred, if I

remember rightly, from low-water mark up to about half tide, in the form of masses like knobs, hummocks, reefs, and plateaux, projecting considerably above the level of the sand. Whether they had been built up to that height by successive generations of the worms forming their tubes on the top of the others, or whether the level of the neighbouring sands had been lowered by the action of currents, tides, waves, or wind, so as to leave the harder masses of tubes projecting, I do not know, but I am inclined to believe that they have been gradually built up inch by inch above the surrounding sand. They are strengthened in many places by the skeletons and bodies of various shore animals, such as large shells, which have doubtless been gradually encrusted over and imbedded; and they give support and shelter to many others, such as Anemones, Ascidians, Sponges, and Zoophytes. These last animals in their turn help to solidify the masses of tubes, and protect them from the waves. The reef, as a whole, must afford very considerable protection to the beach around it, and may possibly result in a gradual raising of the level and growth of the land.

These are a few of the more important instances which have come under my own observation—other, more or less similar cases from tropical seas, such as the formation of coral reefs fringing a shore, require merely a passing mention,—and now I shall briefly enumerate the different groups of animals which I have reason to believe act to a greater or less extent in diminishing the amount of erosion along a coast line.

Foraminifera.—*Planorbulina vulgaris* occurs in such abundance, adhering firmly to the stones, in some parts of Lamlash Bay and the shores of Holy Isle, Arran, as to be a conspicuous feature even to the unaided eye.

Porifera.—Both Calcareous and Fibrous Sponges.

Cœlenterata.—Some Hydroid Zoophytes, such as *Sertularia pumila* and *Campanularia flexuosa*, are exceedingly abundant on certain rocks, and grow so closely as to protect the stone greatly from being rubbed by sand and gravel. Sea-anemones are in some instances very numerous and closely placed. Corals are important.

Echinodermata. — Probably of little importance. Where Star-fishes and Sea-urchins are very abundant they may help. In some cases, however, Echinids bore into rocks.

Vermes.—*Serpula, Spirorbis,* and their allies are in some places exceedingly numerous on rocks and stones. They form hard calcareous tubes, often very closely placed, so as almost to cover the surface.

Polyzoa.—*Lepralia, Membranipora,* and allied forms are very common on stones, and probably have considerable influence. Others have the same effect as Hydroid Zoophytes.

Crustacea.—With the exception of the Cirripedes probably of little importance.

Mollusca.—Gregarious shell-fish, such as Oysters and Mussels, must have considerable effect. Others may be of importance locally if very numerous. Some, such as *Pholas,* bore in rocks. In some places *Chiton* and some species of Nudibranchs are exceedingly common, and are found in large numbers adhering to stones. Some of the Gastropods with strong shells live in large numbers on exposed reefs of rock.

Tunicata.—Some species of both Simple and Compound Ascidians are very common on most coasts. The genus *Botryllus* may be specially mentioned as protecting large areas of rock and stones about low-water mark.

THE MICROSCOPIC CHARACTER OF THE TRIASSIC SANDSTONES OF THE COUNTRY AROUND LIVERPOOL.

By G. H. Morton, F.G.S.

That the structure of sandstone attracted the attention of the curious ages ago is rendered probable by the contents of a work published in 1748 entitled "A History of Fossils," by John Hill, in which 48 pages are devoted to a description of sands and grits. He places them in two orders:—

1st—Arenæ, or Sands; and 2nd—Saburræ, or Gritts.

The Sands are said to be—"Fossils found in minute masses, forming together a kind of powder; the genuine particles of which are all of *one* determinate shape, and appear compleat and regular concretions, not to be dissolved or disunited by water, or formed into a coherent mass with it, but retaining their figure in it, transparent, vitrifiable by a strong fire, and making no effervescence with Acids."

The "Gritts" are described as :—"Fossils found in minute masses, forming together a kind of powder; the several particles of which are of *no* determinate shape, nor have any tendency to one particular figure, but seem the rudely broken fragments of larger masses: not to be dissolved or disunited in water, but retaining their figure in it, and not cohering by means of it into a mass considerably opake, calcining into lime in the fire, and in most of the species fermenting with Acids; often foul'd with heterogeneous matters, and not unfrequently taking in the coarser, stony, mineral and metalline

particles; and hence, as well as from their several colours, subject to various sub-distinctions into Sections."

After this general description of both the orders the author proceeds as follows:—"These are the more obvious and easy distinctions among the species, but there are others always pleasing, and often necessary, especially among such species as seem most to resemble each other; these are their appearance before the Microscope, and the effects of acids and fire on them."

"By these the species will always be certainly distinguished, and on the effects of these are all the following descriptions of the species form'd; it may not be improper to observe to the young student here, that the last of these sets of trials are far from being either troublesome or difficult; the only Microscope I have use'd, as also the particular acid and degree of fire, it may not be improper to mention here, not only for the sake of the young enquirer, but of any other who may be desirous to follow me thro' the experiments; the Microscope was that with the polish'd Speculum, and the glass the second magnifier of that Apparatus, as made by Mr. Cuff; the acid I emply was Aqua Fortis, a thing always at hand, and as made from different salts more proper for these uses than the spirit, or oil of any one alone; and the degree of fire no other than that of a common coal fire, in which the substance to be try'd was kept red hot for a quarter of an hour in the head of a clean tobacco-pipe."

The author minutely describes 54 species of sand and 35 species of grit. The former seem all to have been varieties of sand, for with a single exception the sentence "It makes no effervescence with Aqua Fortis" forms a part of the description of each. The "Gritts," however, in many cases seem to have been limestone, for they

effervesced in acid, though most of them really were grit, or sandstone, between which there is little difference. The species of both orders had been collected in localities all over the world—including Great Britain. In most instances it would be easy to recognise the species or varieties described from the characters given—such as coarseness, shape of grain, colour, brightness, transparency, result of exposure to fire and shaking in water. The locality is given, and often the conditions under which the specimen was found. I will read the description of one of the species of Sand and one of the Grit, so that you will have an idea of the author's exactitude.

ARENA SPLENDIDIOR, ALBA, CRASSA.

LARGE, SHINING, WHITE SAND.

"This is a somewhat coarse sand, considerably heavy, and generally found pure. It is of a good clear white, and very bright and sparkling, composed of seemingly very regular and uniform particles, considerably hard, and very harsh and rough to the touch. Mix'd in water it settles immediately, and leaves no foulness or muddyness in it.

"Examin'd by the Microscope it appears compos'd of very uniform particles, all much of the same size, and all tending to an oblong and irregularly angular shape, perfectly white, of very smooth surface, and all as transparent as white glass.

"It makes no effervescence with Aqua Fortis.

"In the fire it acquires a very slight, and scarce perceptible blush of flesh colour.

"It is found in most parts of the kingdom, and much valu'd by the glass men; a vast quantity of it is brought up to London continually from Maidstone,

and other parts of Kent; and most of the white glass, commonly call'd flint glass of London, is made of it."

SABURRA MICACEA, TENUIOR, ALBO-NIGRESCENS, VARIEGATA.

FINE, VARIEGATED, BLACK AND WHITE GRITT.

"This is a very bright and gay-looking mass; it is considerably fine, but moderately heavy, of a fine bright black and white mottled colour; its constituent particles are very bright and shining in themselves, but the whole is render'd much more splendid, by a plentiful admixture of fine white Talcy flakes, it feels very hard, harsh, and cutting between the fingers, and shook up in water subsides very quickly, and leaves not the least muddiness in it.

"Examin'd by the Microscope, it appears a congeries of very elegant and beautiful particles, part black and opake, and part colourless and pellucid, with all the brightness and fine water of the purest crystal; among these are interspersed not a few flakes of a fine pellucid white Talc, which, with the rest, make a most agreeable object.

"It makes no effervescence with Aqua Fortis.

"It burns to a very pale reddish grey.

"I received it from the shores of the Mediterranean, but could not learn the exact place; it appears evidently the disunited matter of a fine and hard Granite."

The author makes no distinction between the grains of quartz and those of calcite in the specimens he describes, for he considered both to be forms of a different substance, and of a concretionary origin. Throughout the work, however, it is evident the difference between quartz and calcite was well-known in his time, and of rock crystal he states that "The Antients esteem'd it a congelation of water by extream cold, and thought it only ice harder than ordinary."

Only a few pages at the end of the book are devoted to Fossils—the work in reality is on Mineralogy, and anything dug out of the earth was formerly called a fossil. John Hill wrote this work, of which there are three volumes, before chemistry as a science existed—he was one of the pioneers in scientific discovery, and did an enormous amount of work under the most unfavourable conditions.

In many geological works the structure of sandstone has been described. Its general appearance when seen under the naked eye, the pocket lens, or the microscope, is very generally known. Prof. Daubree, Prof. Bonney, and Prof. Hull have directed attention to it. The most important paper on the subject will be found in the Anniversary Address of the President, Dr. H. C. Sorby, F.R.S., to the Geological Society of London so recently as 1880,* and a short abstract of it is given by Prof. Arch. Geikie, F.R.S., in his recent "Text Book of Geology."

It would take up too much of your time, if I were to attempt to give an abstract of Dr. Sorby's researches, so that I must content myself with a few sentences showing the chief results of his observations:—

Grains of sand differ in size from $\frac{1}{25}$ of an inch to $\frac{1}{1000}$, and even less in diameter, but a grain $\frac{1}{100}$ of an inch is the most convenient as a standard of comparison. Although the quartz grains appear very similar to the naked eye, they may be divided into the following five types:—

1st. Normal, angular, fresh-formed sand, as derived almost directly from granite, or schistose rocks.

2nd. Well-worn sand in rounded grains, the original angles being completely lost, and the surface looking like fine ground glass.

* Quar. Jour. Geol. Soc , vol. xxxvi, p. 46.

3rd. Sand mechanically broken into sharp angular chips, showing a glassy fracture.

4th. Sand having the grains chemically corroded, so as to produce a peculiar texture of the surface, differing from that of worn grains or crystals.

5th. Sand in which the grains have a perfect crystalline outline, in some cases undoubtedly due to the deposition of quartz, over rounded, or angular nuclei of ordinary non-crystalline sand.

Sand, though derived in the first instance from granitic, or other similar rocks, may have been used up in the formation of stratified deposits many times over, and on the whole the grains that are the roundest might be expected to be the oldest. The friction of a grain of sand in water is very small, and it may require a much longer time to wear one down than we might at first expect.

The sand in the newest formations, is however, by no means always the most rounded, and Dr. Sorby states that the sand washed from the Boulder-clay at Scarborough "is entirely fresh and angular, showing few or no rounded grains." The grains in the Millstone Grit of Sheffield are also "extremely angular, and, as a rule, show little trace of wearing."

Blown sand is usually very much rounded, for the friction in the air is considerably greater than in water. The sand from the Egyptian Desert is an admirable and extreme example of blown sand; the grains seldom show any sharp angles, and are usually so much worn that the original surface must have been wholly removed. Sand obtained from the shore at Egremont and New Brighton is quite as well-rounded as some from Cairo, but the grains are smaller.

In 1881, Mr. J. Arthur Phillips, F.G.S., read a paper before the Geological Society "On the Constitution

and History of Grits and Sandstones."* He describes the composition and structure of various kinds from Palæozoic, Mesozoic and Cainozoic formations more in detail than Dr. Sorby, and what is of more interest to us, devoted nearly three pages to the description of the sandstone formation of this neighbourhood.

Mr. Phillips describes what he calls the "Millet-seed" sandstone of the Lower and Upper Mottled Sandstones about Liverpool, and the occurrence of minute crystals of quartz attached in many instances to the rounded grains, as represented in a lithograph—magnified 100 diameters. He shows that the crystals were deposited on the grains before the deposition of the ferric hydrates—when the surface was perfectly clean. He is also of opinion that the "Millet-seed" grains originated from blown sand which has since been consolidated into a soft sandstone.

The study of Dr. Sorby's paper shows thoroughly how the structure and composition of sandstone may be examined by the aid of the microscope; while that by Mr. Phillips shows the application of the work to various geological formations; but up to the present time so little has been done that a wide field for future observers is open to anyone who will take the subject in hand and apply it to restricted areas. The sandstone in every geological formation varies so much, that there is no limit to the variety of lithological conditions under which it occurs, in consequence of difference in deposition, composition, and chemical changes that acted upon it afterwards.

Mr. Isaac Roberts, F.G.S., in a paper read before this Society "On the Wells and Water of Liverpool," Session X, 1868–9, describes the microscopic appearance

* Quar. Jour. Geol. Soc., vol. xxxvii, p. 6.

of the New Red Sandstone, and says: "It is an aggregation of hard grains, chiefly quartz—many of them roughly rounded and scratched—many are crystalline, with the angles unbroken, the faces polished like glass, and semi-transparent, and all the grains are attached to one another by a siliceous cement at every point of contact. Most of the grains are white, others are coloured red, blue, and black, and attached to each grain of which the stone is composed are much finer grains, having the appearance of white and red dust, even when viewed under a moderately high magnifying power."

In 1882 I read a paper before the Microscopical Society of Liverpool, and described the character of the sandstone from each of the subdivisions of the Triassic strata of the country around Liverpool. The printed abstract gives the general results, and they are substantially the same as those which have resulted from a still further examination.

Although I had the advantage of a large collection of local sandstones, I found it more recently necessary to visit many quarries within 10 miles of the city, to obtain good normal examples of the various sandstones. I regret to find, however, that the microscope throws but little light on the position of many sandstones in the Triassic series. There are many areas around Liverpool where sandstones occur, the precise position of which is unknown, and although in several instances they present peculiar characters, it would not do to rely on such in determining their relative position. When the position of these doubtful sandstones has been satisfactorily disposed of, the real value of the microscope with regard to such local applications may be more obvious. But with regard to the minute composition of the various sandstones the microscope is

invaluable, and the use of it has in several instances been of importance in confirming conclusions arrived at by other means.

A grain of sand $\frac{1}{100}$ ~~an~~ inch in diameter is a useful standard for comparison, and I have found the use of certain seeds to save using the micrometer.

Millet seed........is about	$\frac{1}{18}$	of an inch	in diameter.
Clover seed	,,	$\frac{1}{15}$	,,	in length.
,, ...	,,	$\frac{1}{25}$	,,	in breadth.
Lobelia seed......	,,	$\frac{1}{70}$	,,	in length.
,, ...	,,	$\frac{1}{100}$	,,	in breadth.
Amaranthus caudatus, or "Love lies bleeding"	,,	$\frac{1}{24}$	,,	in diameter.
Saxifraga umbrosa, or "London Pride".	,,	$\frac{1}{26}$	,,	,,

It is, however, necessary to test the size of the seeds used, for they may be subject to variation, and are only suitable for a rough determination.

It may also be desirable to remind you that the ordinary shore sand at New Brighton and Egremont presents a seed-like aspect, for it is perfectly smooth, and the size of the grains may on the average be $\frac{1}{100}$ of an inch, though there are others $\frac{1}{75}$ and $\frac{1}{200}$ of an inch in diameter, and they seem all equally rounded.

Mr. A. Phillips, in the paper referred to, describes observations he made on the quartz-sand, resulting from the washing of the kaolin, or china clay, at St. Austell. It seems that angular quartz-sand remains for many years on the sea-beach before the angles become rounded. He refers to experiments by Prof. Daubree made artificially on sand, and finally concludes that a grain of sand $\frac{1}{60}$ of an inch would have to travel 3,000 miles mixed with other grains to become rounded. He also says that grains of sand $\frac{1}{250}$ of an inch float in agitated water and never become rounded. The disintegration of granitic rocks is the only possible source of sand.

1.—Hard brown Sandstone, Bore-hole 1290 feet, Bootle Water-works.

Lower Mottled Sandstone (Lower Beds).

Tough, hard, brown, fine-grained sandstone, composed of rounded* grains of quartz, from $\frac{1}{50}$ to $\frac{1}{150}$ of an inch in diameter, in a matrix of fine angular and splintery fragments from $\frac{1}{200}$ to $\frac{1}{5000}$ of an inch in diameter. The largest grains are neither so long nor so abundant as at Tarbock, but present the same worn and smooth appearance. There are also grains of kaolin and mica, with ferric oxide, pyrite and calcite. The sandstone is so hard that when broken the fracture is often through the large quartz-grains. The presence of calcite suggests the strata to be Permian, and it was also found in specimens from the depth of 1039, 1059, 1065 feet. No crystallized grains at 1290, but a few were seen at 1247 feet.

2.—Soft red Sandstone, Stand Quarry, Croxteth.

Lower Mottled Sandstone.

Soft red sandstone, composed of rounded grains of quartz from $\frac{1}{50}$ to $\frac{1}{200}$ of an inch in diameter, coated with ferric oxide. There are also grains of white kaolin not coloured by the ferric oxide.

This sandstone, although composed of rounded grains, has evidently been extensively used as a building stone, as the quarry is a very large one.

* The term *rounded* is used to denote worn grains of sand which may be perfectly round, or of a subangular shape with the edges worn off. The largest grains from $\frac{1}{25}$ to $\frac{1}{50}$ of an inch in diameter, are the most rounded, and are usually quite smooth. At a less diameter they begin to show the angles, and grains smaller than $\frac{1}{100}$ or $\frac{1}{150}$ of an inch are mostly splintery fragments, some of which are only $\frac{1}{1000}$ of an inch in length. In some sandstone, however, the grains are apparently rounded when so small as $\frac{1}{500}$ of an inch in diameter.

3.—Soft yellow Sandstone, Whitfield Lane, Tarbock.

Lower Mottled Sandstone.

Very soft yellow sandstone, composed of rounded grains of quartz and kaolin coated with hydrated ferric oxide. There are large grains of quartz $\frac{1}{25}$ of an inch in diameter, embedded in a matrix of smaller grains, which vary from $\frac{1}{100}$ to fragments $\frac{1}{1000}$ of an inch in diameter. The grains from $\frac{1}{25}$ to $\frac{1}{250}$ of an inch are well rounded and the largest occur in distinct lamina and are quite smooth.

Sandstone of exactly the same character occurs at New Pale in Tarbock, Blue Bell Inn Prescot-road, and at Huyton Church.

4.—Soft red Sandstone, Dacres Bridge, Tarbock.

Lower Mottled Sandstone.

Soft light-red sandstone, composed of rounded seed-like grains of quartz coated with ferric oxide, with kaolin and many grains of a dark coloured undetermined mineral. The grains of quartz are about $\frac{1}{85}$ of an inch in diameter and nearly all of the same size, very few being smaller.

This rock has been used as a building stone, and part of the boundary wall of the adjoining Park is built with it.

5.—Soft yellow Sandstone, Thatto Heath Station.

Lower Mottled Sandstone.

Soft yellow sandstone, composed of rounded grains of quartz from $_{85}$ to $\frac{1}{500}$ of an inch in diameter, coated with hydrated ferric oxide and a few grains and dust of

kaolin. There are some grains of a dark coloured rock. The large quartz grains are the most perfectly rounded, but even the smallest seem to have been more or less waterworn. This sandstone has been thrown up, by a fault, from beneath the Pebble-beds on the east of the section which was described in the Proc. L'pool Geol. Soc., 1871, Vol. 2, p. 56, with woodcut.

6.—Soft red Sandstone, Thatto Heath Station.

Lower Mottled Sandstone.

Soft red sandstone, composed of large rounded grains of quartz $\frac{1}{85}$ of an inch in diameter, in a soft matrix of very minute grains of quartz, kaolin, ferric oxide, and some small flakes of mica. This sandstone is just over the yellow (No. 5), and is remarkably like that from the bottom of the Bore-hole Bootle Water-works (No. 1). It is much softer, but that may arise from weathering, as it is only about 20 feet from the surface, and close to the fault.

7.—Soft brown Sandstone, Collins Green, Sutton.

Lower Mottled Sandstone.

Soft brown sandstone, composed of large quartz grains, coated with ferric oxide, $\frac{1}{25}$ to $\frac{1}{100}$ of an inch in diameter, all well rounded in a matrix of smaller grains, very similar to the sandstone at Tarbock. In sinking the shaft of the Colliery, numerous nodules called "Sulphur balls" by the miners were found at a depth of 300 feet from the surface. They are segregations, or concretions of pyritous sandstone retaining the original stratification, along which the seed-like grains are visible.

8.—Soft Sandstone, Railway section, Rainford.

Lower Mottled Sandstone.

Yellowish-red sandstone, composed of rounded grains of quartz and kaolin, some of the latter being white. The grains are from $\frac{1}{50}$ to $\frac{1}{100}$ of an inch in diameter, in a matrix of smaller grains, $\frac{1}{200}$ of an inch, and other fragments that are much smaller.

9.—Eccleston Hall, near St. Helens.

Lower Mottled Sandstone (Upper Beds).

Soft red sandstone, composed of rounded grains of quartz from $\frac{1}{35}$ to $\frac{1}{200}$ of an inch in diameter, with grains of kaolin, a dark coloured rock and some flakes of mica, It crops out from under the Pebble-beds just south of Eccleston Hall, and may be considered the typical section showing the outcrop of the Lower Mottled Sandstone, but only about 50 feet are exposed. On the west of the Paddock Dam, close to the Hall, some beds of red marl are exposed, which either belong to this subdivision, or the underlying Coal-measures.

10.—Soft red Sandstone, Eastham.

Pebble-beds (Lower beds).

Soft red sandstone, composed of small rounded grains of quartz $\frac{1}{100}$ to $\frac{1}{200}$ of an inch in diameter, in a matrix of minute angular fragments and dust. The grains are coated with ferric oxide, and some present crystallized faces. There are minute flakes of yellow mica, a dark undetermined mineral, with calcite or selenite, and a large proportion of kaolin.

In variety of minerals, quartz crystals and minute

fragments of quartz, the sandstone resembles the Pebble-beds, but it is softer on account of containing a larger quantity of kaolin than usual. It is coloured as Lower Mottled Sandstone on the Geol. Surv. Map.

11.—Hard brown Sandstone, Woolton Quarry.

Pebble-beds (Lower beds).

Hard light-brown sandstone containing numerous quartz and other pebbles. Composed of rounded and crystallized grains of quartz, coated with ferric oxide, from $\frac{1}{50}$ to $\frac{1}{250}$ of an inch in diameter, and minute fragments and dust to $\frac{1}{4000}$ of an inch across. Mica occurs in plates $\frac{1}{100}$ of an inch in diameter, with kaolin and a soft black earthy substance like wad. The quartz grains often present the faces of the 6-sided pyramid and occasionally the prism. Many of the largest grains are covered with minute crystallized planes.

12.—Hard red Sandstone, Littler's Quarry, Knowsley.

Pebble-beds (Lower beds).

Red sandstone so hard as to be almost a quartzite, and composed of rounded grains of quartz, with some of felspar embedded in a more recent quartz matrix. The grains are from $\frac{1}{75}$ to $\frac{1}{100}$ of an inch in diameter, and so firmly cemented together by silica, that when the rock is broken the fracture often runs through them. Some grains have crystallized faces, but obscured in the quartz matrix. The sandstone is so hard that it was formerly much used for making square-sets for the roads about Knowsley, and it is the hardest and most durable building stone in the country around Liverpool.

13.—Hard brown Sandstone, Hawthorne Road, Bootle.

Pebble beds (*Upper beds*).

Light-brown sandstone, composed of grains of quartz, felspar, kaolin, mica, ferric oxide, hematite, a black opaque mineral and a light substance, both undetermined. The grains of quartz vary in size from $\frac{1}{50}$ to $\frac{1}{300}$ of an inch in diameter, and gradually decrease to a dust $\frac{1}{4000}$ of an inch. The largest grains are the most completely rounded, while the smallest are all splintery fragments, and many of the rounded grains are felspar. Many of the quartz grains present crystallized faces of the 6-sided pyramid, and occasionally a prism with a perfect termination. The surface of many of the originally round grains is covered with minute crystallized faces.

14.—Hard brown Sandstone, Low Hill, Liverpool.

Pebble-beds (*Upper beds*).

Hard light-brown sandstone, composed of rounded and crystallized grains of quartz, with mica, kaolin, and ferric oxide. The size of the quartz grains from $\frac{1}{50}$ to $\frac{1}{250}$ of an inch in diameter. Some of the grains seem to have been rounded and afterwards covered with crystallized faces.

Same as the sandstone at Woolton Quarry, but without pebbles, and the sandstone from the Mersey tunnel was found to be exactly the same as this from Low Hill.

15.—Hard brown Sandstone, Bore-hole, 833 feet, Flaybrick, Cheshire.

Pebble-beds (*Upper beds*).

Hard light-brown sandstone, composed of rounded and crystallized grains of quartz, coated with ferric oxide, hematite, mica, and a light-green transparent

mineral not determined. The rounded grains $\frac{1}{100}$ to $\frac{1}{200}$ of an inch in a matrix of small grains and splintery fragments from $\frac{1}{400}$ to $\frac{1}{1000}$ of an inch in diameter.

This sandstone is about the junction of the Pebble-beds with the Upper Mottled Sandstone, and partakes of the characters of both subdivisions, there being no exact line of division between them.

16.—Soft red Sandstone, Dingle, Liverpool.

Upper Mottled Sandstone (Upper beds).

Soft dull-red sandstone, composed of rounded grains of quartz, coated with ferric oxide, from $\frac{1}{50}$ to $\frac{1}{500}$ of an inch in diameter. Even the smallest grains seem somewhat waterworn.

17.—Soft red Sandstone, Crown Street, Liverpool.

Upper Mottled Sandstone (Upper beds).

Soft bright-red sandstone, composed of rounded grains of quartz, coated with ferric oxide, with grains of kaolin and minute flakes of mica. The quartz grains are from $\frac{1}{75}$ to $\frac{1}{250}$ of an inch, with small fragments down to $\frac{1}{1000}$ of an inch in diameter. There are often grains of quartz, and felspar perfectly clean in the mass of red ones.

18.—Soft red Sandstone, Higher Bebington.

Upper Mottled Sandstone (Upper beds).

Soft deep-red sandstone, composed of rounded grains of quartz and a few of kaolin, some of which are white. The quartz grains are coloured by ferric oxide, and are from $\frac{1}{75}$ to $\frac{1}{400}$ of an inch in diameter.

19.—Soft yellow Sandsone, Higher Bebington.

Upper Mottled Sandstone (Upper beds).

Soft bright-yellow sandstone, composed of rounded grains of quartz and a few of kaolin, coated with hydrated ferric oxide, which is scarcely seen under the microscope. The grains are from $\frac{1}{75}$ to $\frac{1}{400}$ of an inch, with many minute fragments to $\frac{1}{1000}$ of an inch in diameter.

20.—Soft red Sandstone, Shaft of Well, West Kirby.

Upper Mottled Sandstone (just below Pebble-beds).

Soft bright-red sandstone, composed of rounded seed-like grains of quartz coated with ferric oxide. The grains are from $\frac{1}{75}$ to $\frac{1}{400}$ of an inch in diameter, and even the smallest have the edges worn off.

21.—Hard red Sandstone, Water-works, West Kirby.

Keuper Sandstone (Basement beds).

Hard light red sandstone, composed of rounded and crystallized grains of quartz and kaolin, with ferric oxide colouring the grains, but occasionally in the form of hematite. The size of the grains varies from $\frac{1}{50}$ to $\frac{1}{100}$ of an inch in diameter, and many present crystallized faces.

22.—Hard brown Sandstone, Harrington-Street, Liverpool.

Keuper Sandstone (Lower beds, near base).

Hard light-brown sandstone, composed of rounded grains of quartz, and many covered with crystallized faces, $\frac{1}{75}$ to $\frac{1}{250}$ of an inch in diameter. Rounded grains and fragments of felspar and kaolin from $\frac{1}{100}$ of an inch to a dust, with ferric oxide. There is also some quartz in minute fragments, and in the form of dust down to $\frac{1}{5000}$ of an inch in diameter.

Good building stone, and formerly much used about the south end of Liverpool.

23.—HARD BROWN SANDSTONE, ELLENBROUGH STREET, LIVERPOOL.

Keuper Sandstone (Lower beds).

Hard light-brown sandstone, composed of rounded grains, and many covered with crystallized faces, $\frac{1}{75}$ to $\frac{1}{250}$ of an inch in diameter. Rounded grains and fragments of felspar and kaolin from $\frac{1}{100}$ of an inch to powder or dust. In addition to the coating of ferric oxide there are some grains of the mineral. There are also minute fragments and quartz dust from $\frac{1}{250}$ to $\frac{1}{5000}$ of an inch in diameter.

24.—SOFT YELLOW SANDSTONE, LONDON-ROAD, LIVERPOOL.

Keuper Sandstone (Upper Beds).

Soft yellow sandstone, composed of rounded grains of quartz, felspar, and kaolin, the latter mostly in the form of dust or powder. The felspar is probably orthoclase, as it exhibits the cleavage planes of that mineral. Both quartz and felspar grains vary from $\frac{1}{75}$ to $\frac{1}{250}$ of an inch in diameter, and gradually assume the form of minute fragments and dust to $\frac{1}{5000}$ of an inch. There are a few crystallized faces, much obscured by the large quantity of kaolin which forms half the rock.

25.—WHITE SANDSTONE, STORETON QUARRIES, BEBINGTON.

Keuper Sandstone (Upper Beds).

Hard white sandstone, composed of rounded grains of quartz, felspathic dust, and occasionally minute black grains with a bright conchoidal fracture like obsidian. The quartz grains are colourless, and vary in diameter

from $\frac{1}{100}$ to $\frac{1}{200}$ of an inch. Some are of a pink shade, and it seems probable that they are held together by silica, though there are no crystals, or other indications of it.

Esteemed as a building stone, but not always durable.

26.—Arenaceous Shale, Storeton Quarries, Higher Bebington.

Waterstones (Base of Red Marl).

Soft sandy shale, composed of minute grains of quartz, about $\frac{1}{200}$ to $\frac{1}{1000}$ of an inch in diameter, with mica and kaolin. The mica occurs in flakes $\frac{1}{50}$ of an an inch across, and others much less, and in laminæ as well as distributed throughout the shale.

The foregoing microscopic description of the Triassic Sandstones around Liverpool shows that there are four normal types, although they run, more or less, into each other.

1st.—Fine grained sandstone, composed of small rounded and subangular worn grains of quartz, of nearly uniform size.

2nd.—Fine grained sandstone, composed of small rounded and subangular worn grains of quartz, containing a great number of larger grains, $\frac{1}{25}$ to $\frac{1}{50}$ of an inch in diameter, like a minute or very fine grained conglomerate.

3rd.—Fine grained sandstone, composed of small rounded and subangular worn and crystallized grains of quartz, associated with very minute grains and fragments, which are not worn. The crystallized faces on the rounded grains having been formed after the sandstone.

4th.—Fine grained sandstone, or quartzite; which was originally formed of small rounded and subangular worn grains, but which have been united by the deposition of silica into a hard and compact mass after the formation of the sandstone.

The Lower Mottled Sandstone is very similar to the Upper Mottled Sandstone, the only difference being that it usually contains larger worn grains of quartz, from $\frac{1}{25}$ to $\frac{1}{35}$ of an inch in diameter. In several borings that have reached the Coal-measures, the sandstone below the Pebble-beds has been found to consist of these large seed-like grains. Strata at Croxteth, Tarbock, and Rainford, supposed to be Lower Mottled Sandstone, all occur in localities where the geological horizon is uncertain, but the large seed-like grains go far to prove that they belong to that subivision. Several sections formerly supposed to expose the Lower Mottled have since been shown to belong to the Upper Mottled Sandstone, or to soft beds near the base of the Pebble-beds. For example, the Upper Mottled at Grange Hill, West Kirby, was formerly considered to be the Lower Mottled Sandstone cropping out from under the Pebble-beds, but it has since been shewn that the section exposes the base of the Keuper with the Upper Mottled Sandstone beneath it. Another example occurs at Eastham, on the shore close to the Hotel, where soft beds of sandstone crop out from under the Pebble-beds; but the microscopical character of both the soft and the hard beds being almost identical, there is little or no doubt that they both belong to the same subdivision, though the soft sandstone contains a larger portion of kaolin, and consequently disintegrates and assumes a sandy appearance.

At Eccleston Hall, north of Eccleston Hill, the Lower Mottled Sandstone appears to crop out from below the

Pebble-beds as shown on the Geol. Surv. Map. The former subdivision is represented by about 50 feet of soft red sandstone of a seed-like character, though there are no beds of marl exposed such as often separate the Pebble-beds from the Lower Mottled Sandstone. In a recent boring at Holt Lane Bridge, the soft seed-like sandstone was found to be interstratified with thick beds of red marl, so that the section exposed near Eccleston Hall may be considered to be the best exposure that is available for examination, and to be above the marls.

The hard brown sandstone forming the Pebble-beds is composed of rounded and sub-angular worn and crystallized grains of quartz, associated with minute splintery grains and fragments. Kaolin in the form of grains and dust forms a conspicuous portion of the rock. The typical sandstone of the Pebble-beds is almost a true grit formed of angular grains, but the angularity is in consequence of the crystallization of more recent quartz in planes or faces over the exterior of the originally rounded grains.* The hardness and toughness of the Pebble-beds as a building stone arise from its compact and felted structure—the interstices between the quartz grains being filled up with a fine dust of quartz and kaolin and the whole cemented together by ferric oxide and silica.

The Upper Mottled Sandstone is composed of small seed-like grains of quartz, and is often yellow, though generally of a bright red colour. Occasionally there are grains $\frac{1}{35}$ of an inch in diameter, as at Scarth Hill, near Ormskirk, and at Flaybrick Hill, near Birkenhead, but they are not common, and the average size

* The formation of crystals on grains of sand was first described by Prof. T. G. Bonney, F.R.S., Jour. Geol. Soc., Vol. xxxv, p. 666.

of the most conspicuous grains is about $\frac{1}{100}$ of an inch. The large grains and a few crystallized grains were found near the bottom of the Upper Mottled Sandstone in the Railway cutting in Crown Street, and from more extended observations it seems impossible to draw an exact line between that subdivision and the underlying Pebble-beds. Although the Upper Mottled Sandstone has no definite base, it ends abruptly at the top, with the Keuper Sandstone resting on its eroded surface.

The Keuper Sandstone varies considerably in its microscopical characters, and that at the base of the subdivision cannot be distinguished from that of the Pebble-beds.* It is composed of rounded and angular worn grains of quartz, many of which are covered with crystallized faces of a more recent deposit. Higher in the Keuper series the sandstone is generally formed of rounded grains, and much resembles that of the Upper Mottled Sandstone, though usually much harder. There are other beds of sandstone associated with the Keuper remarkable for the large proportion of kaolin they contain and the occurrence of crystallized grains of quartz.

It seems probable that the quartz and other minerals forming the Triassic Sandstones around Liverpool were derived from two or three different sources, and that the varying character of the sandstone deposited at successive periods, was caused by physical changes that altered the direction of the currents and the source of the sand. But the chief difference between the various sandstones has resulted from chemical changes that have occurred since the original deposition of the sandstone.

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* Mr. T. Mellard Reade, F.G.S., informed me that he had seen the sandstone from the Keuper beds at Runcorn and from the Pebble-beds at Bootle, used in the construction of the same building, and that there was no perceptible difference.

THE MERSEY TUNNEL: ITS GEOLOGICAL ASPECTS AND RESULTS.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

Few engineering works have excited more interest than the tunnelling under the bed of the Mersey, now practically completed. It had all the elements to take possession of the imagination—great commercial importance, boldness of conception, and just that spice of uncertainty without which, being human, we can scarcely be thoroughly interested.

It is not my object to give a history of the undertaking; but commencing at the time that I myself began to feel an interest in the subject from a geological point of view, I will attempt an outline sketch of the ideas that prevailed as to the nature of the river bed between Liverpool and Birkenhead.

In 1870 I found that the general impression was that a "shelf of rock" extended across the river from Seacombe Point to Prince's Dock. That is, that the bed of the river, excepting for a certain superficial deposit of mud and sand, was rock all the way across. I found, however, from conversations with several experienced master pilots that this view was not well founded, although they were of opinion that it was rocky bottom from the Birkenhead side a considerable distance across.

A series of borings from Warrington down the valley of the Mersey to Runcorn, and especially under the town of Widnes, led me to the conclusion that the rocky bed of the Mersey between Warrington and Liverpool was a river valley, and not two rock basins connected, as some eminent geologists supposed. My reasons for this conclusion were fully stated in a paper entitled "The

Buried Valley of the Mersey," read before this Society on January 14th, 1873.

At the time that paper was written I was in possession of borings shewing the depth of the rock over the area of the Great Float at Birkenhead, which conclusively proved that the pre-glacial outlet of the river could not have been in that direction. From many considerations which I cannot recapitulate here, I came to the conclusion that there was a deep depression or gully in the river between Liverpool and Birkenhead filled with drift, and this was strongly stated and reiterated in a concluding note in my paper.

Since then the subject has been frequently discussed at this Society, and the information I from time to time obtained tended to strengthen my original conviction that the Mersey Tunnel works would be sure to disclose this pre-glacial valley.

The excavations of the Atlantic Docks at the mouth of the river, disclosed the existence of branching gullies in the rock, deep below low-water mark* and apparently flowing towards the channel of the Mersey. This to my mind, completed the evidence that the river formerly as now, flowed past Liverpool, but at a considerably lower level.

In a letter to the "Builder," Feburary 4th, 1882, while the Tunnel works were in progress, I restated the facts upon which I had based these conclusions, and on frequent occasions, at public lectures, at our visit to the Atlantic Docks, and in this room, I have maintained the same view.

I trust that these remarks may not be considered egotistical; they are in fact necessary to show practical

* "The Drift Beds of the North West of England," Part ii., Q.J.G.S., May 1883.

men that geology has, in some instances, attained to the rank of a science. We can *previse.*

So much for prophecy. Now I propose giving a sketch of the actual geological results as disclosed by the Tunnel works, leaving the exact figures and levels for a future occasion.

The drainage headings, which are considerably below the rail level of the Tunnel on the banks of the river, and gradually rise up on either side, until the level portion of the railway under the centre of the river is reached, were successfully driven and bored through the rock from either side until they met on January 17th, and several people had the gratification, and novel sensation, of walking through under the river, from Liverpool to Birkenhead.

In the actual Tunnel, at some 800 yards from the Liverpool side, the bottom of the pre-glacial valley was intersected by the upper part of the Tunnel, the roof for about 100 yards being in hard Boulder-clay. Before this was all arched in, I had the opportunity and pleasure of inspecting it, my emotions being on this occasion rather "mixed"—delight at seeing what I had dreamt of for twelve years past, and pleasure at finding that my friends were getting so well out of their difficulty, and that this important work was practically, a *fait accompli.*

The rock forming the bed of the gully was good and solid, and swept clear of the débris which often lies between the Boulder-clay and the rock. Upon this reposed the hard Boulder-clay, which was of a similar nature to Bed No. 2, described in the section of the Atlantic Docks, in page 88 of my "Drift Beds of the N.W. of England," Q.J.G.S., May, 1883. It contained similar boulders of Eskdale and other granites, trappean

rocks and greywackes, generally much water-worn, as they often are in these lower beds of Boulder-clay. In one place I observed a thin seam of yellow sand between the Boulder-clay and the rock; it evidently belonged to the lower bed of the "Low-level Boulder-clay and Sands."

As regards the rock, the dip is from Birkenhead to Liverpool, at about 10°, and I am informed that a fault was met with near the middle of the river, but this proved to be water-tight. The rock on the Birkenhead side I know, from having been in the lower heading while Major Beaumont's machine was boring it, was very hard and compact. The rock on the Liverpool side was softer, and more thinly bedded. All of this rock evidently belongs to the division of the Bunter which is called the Pebble-beds, but probably the rock on the Birkenhead side is at a lower horizon than that on the Liverpool side. The rock under the river was remarkably homogenous throughout, and comparatively free from faults. The throw of this one fault is unfortunately not known. Perhaps when the engineers publish their sections, we may know more about it.

At St. George's Church, Liverpool, I am told another fault was met with, and here the Tunnel is in a much softer rock. Opposite to Stonier's shop, in Lord Street, the Tunnel intersects the bottom of a branch to the Old Pool, filled up with recent silt, and similar to what is met with in the foundations along the line of the Old Pool. Opposite to Whitechapel and Seel's Buildings, the bottom of the Old Pool was touched. Beyond this the Tunnel is in rock, shading off at the top to red sand, covered with a thin bed of Boulder-clay.

This portion I am well acquainted with, having had to inspect it for the Liverpool Tramways Company.

Borings in the Upper Reaches of the Mersey.—Since

the publication of "The Buried Valley of the Mersey" a series of borings has been taken by Mr. George Hill, C.E., across the bed of the Mersey from Weston Point to Hale Head, for the Upper-Mersey Navigation Commissioners. It was supposed that the river was obstructed by rock, which if removed would much improve the navigation. So far from this being found to be the case, the existence of a rock valley was proved, the deepest part bored being 84 feet below Ordnance Datum. This valley was filled up with gravel, peat, and sand.

A bore was also made in the river opposite Hale Head, by the London and North-Western Railway Company during the Manchester Canal contest, for the particulars of which I am indebted to Mr. Thos. S. Keyte, C.E. After 17 feet of river-sand and gravel were passed through hard Boulder-clay was entered, and then a series of quicksands, clays and gravels, terminating 62 feet below Ordnance Datum without reaching the rock.

I learn from our Secretary, Mr. Morton, that near to Mr. G. M. Williams' house at Hale Cliff, the rock is overlaid by about 130 feet of Boulder-clay.

At Halewood, about ¾ of a mile from Hunt's Cross Station, a boring showed a depth of 137 feet of drift, the bottom bed being gravel 8 feet thick, resting upon Keuper Marl. The surface of the marl was about 37 feet below Ordnance Datum.

WHAT FURTHER LIGHT DO THE FOREGOING FACTS THROW UPON THE PHYSICAL HISTORY OF THE MERSEY VALLEY?

For certain reasons, I am not now prepared to state the exact level of the pre-glacial valley intersected by the Mersey Tunnel, further than to say that it is not so deep as the portion under the town of Widnes. That it is a true valley and not a lake-basin, I pointed out

twelve years ago. The entire absence of lacustrine deposits under the Boulder-clay proves this. The branching gullies met with so frequently by borings on the margin of the river, the form of the rock valley between Weston Point and Hale Head, and the proved continuity of the valley between Warrington and Liverpool, point to the same inference. If, then, this reasoning be valid, unless we suppose an outlet existed by the River Dee—of which we have no proof, and which would seem a far-fetched explanation—we seem to be driven for an explanation to differential subsidence of the land *since* the rock valley was filled with marine "Low-level Boulder-clay and Sands."

It is well known that during the glacial period what is called "the great subsidence" occurred. On Moel Tryfaen, about 60 miles from here in a south-westerly direction, marine shells are found at an elevation of 1,400 feet; and there are grounds for thinking, with Sir Andrew Ramsay, that the subsidence reached 2,000 feet in Wales. The subsidence was very general and over a large area, evidences of it being found both in Ireland and Scotland. It is, however, absolutely unknown to what extent this vertical land movement affected the relative levels of the land surfaces. In addition to this movement, when the rocky gullies we are now considering were eroded and scooped out by running water, the land must have stood at a higher elevation than at present. This vertical movement, the extent of which is unknown, must be added to the great subsidence if we are to realise the total vertical subsidence of the land. The cause and nature of these land movements is at present unknown. They do not appear to have been accompanied by faulting, but this cannot positively be affirmed. No doubt in course of time observations such as I now

have the honour to lay before you, will enable us to solve many of the difficulties; but, as you will perceive, it is a painfully slow process. It seems, however, reasonable to conclude that the movement of these great land masses must be to some extent of a differential nature; and it is easy to conceive that a difference of 50 feet, say, between Widnes and Liverpool might in that way arise without it being perceptible by any surface dislocations. The distance in a direct line is about 12 miles, and this would only amount to a differential gradient of 1 in 1,200. It would in fact only constitute a curve-like bending of the earth.

Before dismissing this aspect of the physical history of the Mersey Valley, I would call attention to the fact that even later or Post-glacial land-movements, shew a differential vertical rise or fall. There is, for instance, the well known 25 feet beach, found on the west coast of Scotland. This shades off to a few feet in Morecambe Bay, while in the neighbourhood of Liverpool there is an actual Post-glacial subsidence; but I must confess that the relation of these movements has never been accurately defined. At the present moment there is a slow change of level going on, in the coast of the Baltic. In 1750 there was set up a series of water-marks all round the Swedish coasts, from the mouth of the Tornea to the Naze, to settle a dispute between the Swedish astronomer Celsius and some Germans, as to whether the level of the Baltic had been rising or sinking. The gauges were renewed in 1851, and again this year, and have been inspected regularly at short intervals, the observations being carefully recorded. The result is that the Swedish coast has been steadily rising, while that on the southern fringe of the Baltic has been as steadily falling. In 134 years the north part of Sweden has

risen about 7 feet, the rate of elevation gradually declining to about 1 foot at the Naze, and nothing at Bornholm, which remains at the same level as in the middle of last century. "Nature," Dec. 18, 1884, p. 150.

It is evident that if the *differential* subsidence of the Mersey Valley began with the subsidence of the land which the pre-glacial valley drained, and the valley and its tributaries became filled with marine Boulder-clay, as we find it is, the absence of anything like later deposits lying upon the rock under the Boulder-clay is satisfactorily accounted for.

THE EROSION OF THE PRE-GLACIAL CHANNEL OF THE MERSEY.

The history of the scooping out of the rocky valley of the Mersey between Liverpool and Birkenhead is of considerable interest. You will remember that the rock on the Birkenhead side was more compact and harder than that on the Liverpool side. The beds also dip from Birkenhead to Liverpool; also there is a fault in the centre of the river. It is a fact that has been noticed by Prof. Hull, our Secretary Mr. Morton, and others, that the river valleys about here have a tendency to follow the strike of the rocks. The Mersey channel to a considerable extent obeys this law, and it has evidently, commencing at a higher level near the Birkenhead side, sawed its way laterally down the bedding plains, reaching the softer but still pretty hard rock on the Liverpool side, guided to some extent by the line of fault. What initiated the direction and position of the Mersey Valley is a complicated question, shrouded in the mystery of geological time, which much further investigation is needed to determine. But of this we may be pretty well assured, that the river has not chosen the harder rocks to erode

by preference, but that formerly they were covered with rocks of a softer nature higher in the series, and that the river has eaten down to and exposed the harder beds. Then follows the result, which is expressed in the term "hard-gorge theory." That is, the inner basin of the river being composed of softer rocks, widens by vertical and lateral denudation, while the outlet in the hard rock narrows and deepens. This, with the differential subsidence already spoken of, accounts for the remarkable bottle-shaped form of the Estuary of the Mersey, and its natural adaptability for a Port.

POST-GLACIAL CHANNEL OF THE MERSEY, AND THE HISTORY OF ITS FORMATION.

I must now ask you to carry yourself back in imagination, to the time when the land slowly emerged from the deep, after the great subsidence. The whole country was covered with a mantle of Boulder-clay, sands, and gravels, the pre-glacial valleys being filled up, and to some extent obliterated by these glacial deposits. The land as it emerged, became subject to the influence of rain, which cut channels through the drift in the readiest way it could to get to the sea. Hence the surface form of the drift would largely determine the course of the rivers. It follows from this, that in some cases the river Mersey left its old channels. It changed laterally its pre-glacial site at Widnes to the gorge at Runcorn, removing the Boulder-clay from that gorge down to the rock. Once sufficiently sunk into, and settled in its course through the glacial deposits, the position of the Post-glacial river Mersey became fixed. Judging from the sections I lay before you, the current of the Mersey, again running at a higher level, with respect to the sea, as a fresh water river, then as now, followed what was formerly a tributary only of the old

stream. It scooped out all the glacial deposits to the rock, and filled the bed with gravels, peat, and sand, as the section between Hale Head and Widnes shews. It scooped out the glacial beds that filled up the gorge between Liverpool and Birkenhead, which on the subsidence of the river to its present level was aided by the tidal in-rush and out-pour, so remarkable a feature in our noble estuary. Fortunately for the Tunnel works, the hard Boulder-clay filling up the deeper parts of the valley was left, it may be by the course of the fresh water river having bottomed the rock nearer to Birkenhead, or because the river had reached what is called the "base level of erosion," and from lack of gradient could not clear its bed further. Doubtless there were formerly Post-glacial deposits in the river, between Birkenhead and Liverpool, as there are nearer Runcorn; but if so, they have been scoured out by the tidal stream. The interesting series of borings, taken by Mr. Charles H. Beloe, C.E., while the Manchester Canal was being opposed, which I am enabled through his courtesy to lay before you to-night, shew that there is a great depth of gravel overlying the Boulder-clay, in the river-bed between Garston and Runcorn. This gravel I consider is Post-glacial, and due to the destruction of the Boulder-clay.

This district is doubtless looked upon with horror by geologists whose sport is Palæontology; for, saving a few footprints, there is not a fossil to be found in the New Red Sandstone. Looking deeper into the history and geological genesis of things from a physical point of view, the problems presented for our solution are to my mind supremely interesting, and calculated to throw light upon questions of vast importance, and to aid us in unravelling the tangled skein of history which our Mother Earth has spun for us.

A QUARRY AT POULTON, AND THE RELATION OF THE GLACIAL MARKINGS THERE TO OTHERS IN THE NEIGHBOURHOOD.

By H. C. Beasley.

The object I had in view in preparing this paper was to bring before your notice some glacial markings exposed in a quarry at Poulton and also near Wallasey Windmill. I afterwards thought it would be well to consider them in relation to others at Flaybrick Hill and other places near; and as I proceeded I was tempted to wander still further from my original intention by noticing one or two other things in the quarry at Poulton not bearing on glacial matters, which, with your permission, I propose also briefly to describe.

In looking through the Proceedings of this Society I do not see any papers referring to glacial striæ since the Session of 1876–7, when we had communications from our President, from Dr. Ricketts, and from Mr. Morton on the subject; the latter giving us a most useful list of the localities and direction of striæ in the country round Liverpool, with remarks upon them. I have found the list most useful, and shew several of the localities and directions on the two sheets of the Ordnance Survey before you, and others in the list beside it.

I have to acknowledge my indebtedness for many valuable suggestions from our President and Mr. Jeffs, of whose company I have had the pleasure and advantage in a visit to the localities described.

The quarry at Poulton is situated 800 yards in a direct line north of the Halfpenny Bridge over Wallasey Pool, close to the monument recording the death of Mrs. Boode, on the east side of the road to Wallasey.

It is in the Keuper Sandstone, which here is nearly horizontal, having a very slight dip towards the south: it is about 20 feet deep, and perhaps 100 yards long from north to south. It is much fissured and jointed, the joints generally running W.N.W. and E.S.E. The beds run pretty evenly the whole length of the quarry, there being but little vertical displacement visible. There are two points about these joints which I think perhaps worth mentioning: two of them near the southern end of the quarry are open nearly the whole height of the quarry and as far back as can be seen; the openings are from 4 to 6 inches wide.

Near the northern end of the quarry one face of a joint is exposed. The joint is a closed one, but the part of the face exposed (which is about 3 or 4 feet wide, and the whole height of the quarry) is covered with Slickensides and very distinctly striated *horizontally*. The joint itself is vertical; the bedding, as I said before, is horizontal. Whether the horizontal movement here indicated has anything to do with the opening of the joints at the other end of the quarry, is a point worth investigating.*

The upper layer of rock is about 4 feet thick and is tolerably compact at its southern extremity, but becomes more and more fissured northwards, until about the middle of the quarry it becomes a breccia of angular

* Since writing this paper, Mr. Reade has pointed out another horizontally Slickensided joint a few yards further north, but the joints are not parallel, the more northerly one bearing 75° W. of N., the other one 67° W. of N., whilst the open joints at the southern end of the quarry have a direction of about 50° W. of N.

fragments, from an inch to two feet in diameter, lying in all positions, and cemented together in a coarse sandy matrix.

Lower down, in almost the lowest part exposed, is a bed of ferruginous conglomerate, very friable at one part, but passing horizontally into a solid rock. It is of no great thickness. This probably represents the conglomerate at the base of the Keuper.

Viewed from the opposite side of the quarry, the upper edge of the rock forms a very distinct, sharp, horizontal line, more especially at the southern end. This is overlain by clay with stones, some scratched, and surface-soil, together from 18 inches to 2 feet or more in thickness.

In three places the overlying clay has been removed, leaving the surface of the rock exposed for about 5 or 6 yards square. In each case the surface is glaciated, and I shall refer to them as exposures 1, 2, and 3, beginning from the South. They lie about 80 feet above Ordnance Datum, at the top of the escarpment that slopes rapidly towards Wallasey Pool.

No. 1 is near the southern end, and shews a well preserved surface, something over 6 yards square, smoothed, grooved, and striated all over; the markings varying from very fine Striæ, to grooves an inch across.

The directions of by far the greater number lie between 27° and 32° west of north, and the direction of the principal striation may be taken as 30° west of north. But there are others that vary considerably; on one part there are markings only 19° west of north, a few others are 38° west of north, and one as deep as any, is 44° west of north, so that they vary about 25°; but all these markings are of the same character, and look as if made about the same time and under the same circumstances.

There is however in places a distinct cross striation nearly at right angles to the other, as shewn in the rubbing before you, its principal direction being 22° south of west. These striæ are not quite so wide or so deep as the others, and widen out at the edge of any irregularity on the surface, either at the eastern or western ends. Mr. Reade informs me that the cross striation described by him at Miller's Bridge (Proceedings of the Liverpool Geological Society, Session 1876-7,) shewed a similar widening.

I carefully examined the pebbles projecting from the face of the glaciated surface; unfortunately they were not numerous, but they were generally, in fact always where worn at all, worn into a gentle slope at their *southern* end, and ended bluntly towards the north, indicating a movement *towards the north.* The whole surface is also gently rounded to the south.

There has apparently been some slight dislocation of this surface since glaciation, for one part is raised two or three inches above the rest along a fracture, the edge are not rounded, and the grooves extend unaltered to both edges, as far as I could see. There is a piece of rock projecting somewhat above the general level, which has one side smoothed quite flat, at about 45° to the horizon, the direction of its upper edge being 45° W. of N., and it is marked with parallel markings in the same direction. It is difficult to account for this, as there are no other markings on the exposure in the same direction except the one before mentioned.

No. 2 Exposure is just where the more solid rock is passing into a breccia. The markings are not so numerous or quite so distinct as on No. 1, but they are all in or near the line of principal striation. I did not see any very divergent striæ, nor was there any trace of

the cross striation. The markings are very distinct across a broken piece of rock, being a part of the breccia rising somewhat above the rest of the surface; but it is not so clearly rounded as might have been expected. There are two small but distinct grooves that are rather crooked, though their general direction is the same as the rest. All the other markings are quite straight.

No. 3 Exposure is entirely on the breccia. At first sight, and before seeing the upper surface, the appearance of the rock suggested that it might have been broken up by the movement of the ice that caused the markings on the other exposures, and the interstices at a later date filled in from the overlying clay; but on closer observation it was found that the angular blocks lay in a matrix of coarse sand, and were firmly cemented together to form a breccia; and on examining the exposed upper surface it was found to be striated just as the other exposures were, and there was also the cross striation similar to that on No. 1. The surface was of course very irregular, but the markings very distinct, so that it must have been as consolidated as at present when they were caused. I should think, however, that the breccia was due to ice action of some kind, but at an earlier period.

WALLASEY.—From the quarry at Poulton the surface of the hill slopes gently upwards to Wallasey Windmill, a distance of about half a mile. By the side of a quarry close by the mill and on almost the very highest point of the hill, I found an exposed surface several yards long, covered with very even striæ remarkably parallel, bearing 30° to 32° W. of N. (The same as at Poulton). They lie considerably above the 100 feet contour line.

We will now compare them with markings on the other side the valley not quite a mile away, at

Flaybrick Hill.—The glacial markings on this hill have been long known—in fact, some of the earliest recorded in this neighbourhood were found here. A good many of those previously recorded have now vanished, having been weathered or quarried away.

For the last few years there has been exposed at the foot of the hill, just south of St. James' Church, a short distance east of Tollemache Road, a portion of a beautifully rounded and striated surface of sandstone. A still further portion has lately been uncovered, so that it can be traced for about 100 yards on the south side of Lansdowne Road, but it is only a few yards wide on the widest part. The striæ, which are very numerous, have the same direction as those I have before described, viz., 30° to 32° W. of N. I only noticed extreme variation covered by 4 degrees, except on a small patch at the eastern side, where they vary rather more. They are rather more than 50 feet above O. D. These have been noticed and recorded by the Geological Association, and are there spoken of as running N. and S. This is now being rapidly quarried away.

The rock is now overlain, where not exposed, by 4 feet of Boulder-clay in situ containing minute fragments of shells. Above this is some surface soil and grass, the original surface of the hill, nearly following the curve of the rock surface, and upon this a quantity of clay removed to its present position in the course of quarrying operations. The upper boundary of the exposure has at one time formed the face of a quarry and is now hidden by the remains of a spoil bank. Beyond it the rock has been quarried away for some distance; but crossing the quarry 100 yards or so to the S.W., I found a small portion of the surface exposed striated 30° to 32° W. of N., and from its position

(at a higher level) and angle of slope it evidently was an extension in that direction of the glaciated surface before described; and about S.E. of that and about 100 yards off I found another similar exposure similarly striated, so that there was at one time evidently a beautifully rounded and glaciated surface at least some 10,000 yards in extent—probably much more—thus justifying a remark of Mr. Morton's in one of his papers, that the hill owes its present shape more to the action of ice than of water.

I think it must be to a part of this area that Mr. Mackintosh referred in his paper before the Geological Society in London, in 1877.

The upper part of this surface is about level with that at Poulton, and, as we have seen, the striæ have the same direction.

Mr. Mackintosh has described some striæ at a rather higher level, ½ mile south of St. James' Church, as 30° south of west, which would answer to the cross striations at Poulton and Miller's Bridge, and I have observed some very much weathered markings 30° W. of north, near the position indicated.

The author here exhibited two sheets of the 6-inch Ordnance Maps of the district, with the recorded striæ marked upon them, showing a very general parallelism of striæ in a direction within a few degrees of 30° W. of N., and continued: "I think we are warranted in concluding that these markings are due to the action of a sheet of ice, covering a very considerable area, and of considerable thickness, and at least four miles wide."

The evidence at the Poulton Quarry is, as I said, in favour of a movement towards the north, or rather N.N.W., and I think this is confirmed by what we can see of the shape of Flaybrick Hill, where there is a gentle

slope on the south-east, and a steep natural escarpment at the northern end. The outline of the hill has been much altered by quarrying, and it is difficult to speak positively, but it seems to me that it forms a gigantic Roche moutonnée.

I know that I may seem to be setting my own against the very general opinion, that there was a great ice sheet moving south, from Scotland and the lake district, over this district; but I do not think I have given the amount of attention to this large subject, to warrant my saying anything about its existence or otherwise; but if it did exist at the most severe part of the glacial period, it does not follow that later on, smaller ice-sheets did not exist flowing towards the sea.

The Triassic Sandstone is a comparatively soft stone, and any markings upon it we know by experience, are rapidly weathered away, and I do not think that a retreating glacier has left these exposed to the air, there is no trace of a moraine having covered them; if it once did, they would have been worn away in process of its removal. So the probabilities are, that the ice continued to protect them until submerged, if they were not actually formed below the water level.

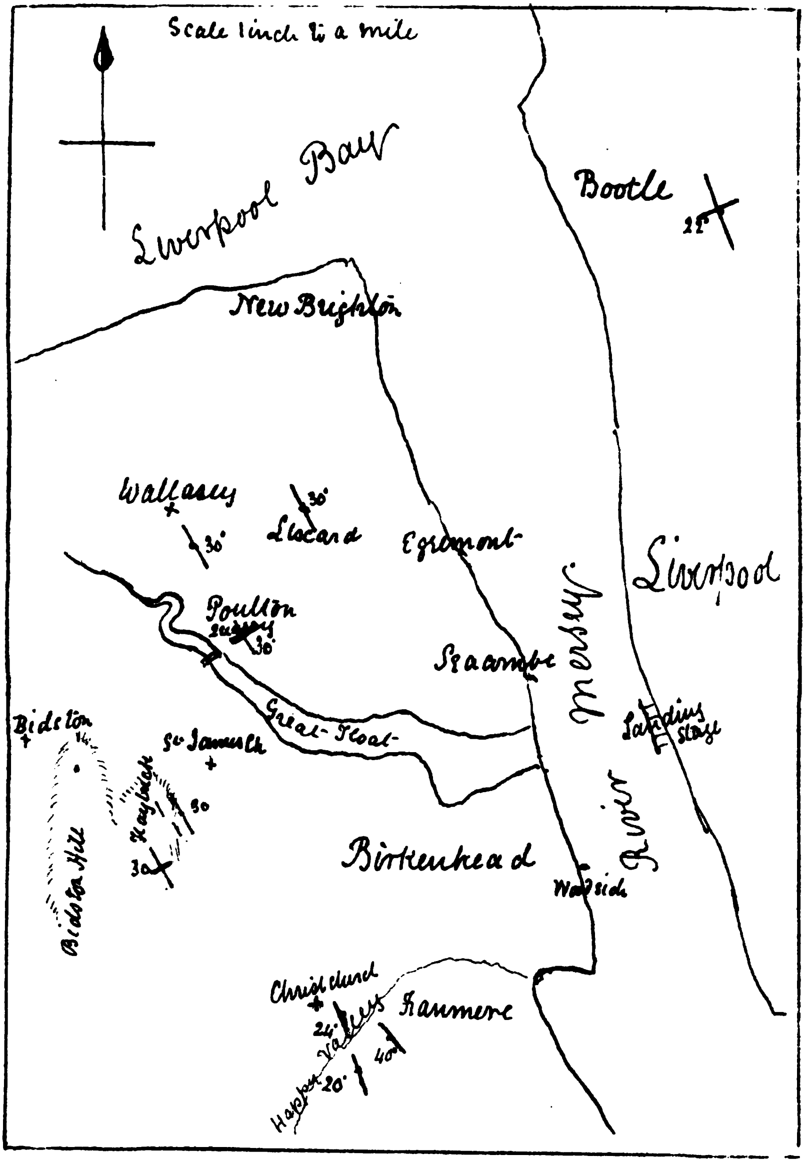
Once beneath the action of the waves, they would be safe from further wear, except from ice-bergs, which would be constantly breaking off from the glacier; in fact the very piece of ice that covered them may in floating away have grazed them, and caused the cross striations, and I think this view is borne out to some extent by facts.

You will remember that the cross striations at Poulton, and at Miller's Bridge, were characterised by a widening at the ends as if a small triangular piece had been chipped out before the groove was fairly started,

and this is what we might expect from the sudden impact of a piece of rock, firmly embedded in the base of an ice-berg: but the very slow and regular pressure of a glacier would not be so likely to have that effect, and I see no reason to doubt that a tidal or other current, set at right angles to the line of movement of the glacier. The direction of the three instances of cross striation certainly lends probability to this.

The divergent striæ have, I think, a different origin; they are confined to within 10 or 15 degrees of the main striation. They are generally attributed to fragments of rock in the base of the glacier changing their position; and although this somewhat vague explanation is not altogether satisfactory, I cannot suggest a better. I have not heard of these divergent striæ having been noticed in the beds of more modern glaciers, except on the sides, and also on the junction of two streams of ice, where the varying force of one or other stream varies the direction of the current; but I hardly think that these conditions prevailed at Poulton.

With reference to movements of fragments of rock to the base of the glacier, we must remember that, should a rock be so firm that the ice cannot move it, the ice moves over and round it, and where a fragment of rock in the base of a glacier meets with resistance (as it would whilst grooving the rock below), its movement is more or less retarded, and to that extent the ice flows past it. Therefore it must be possible, under certain circumstances, for the balance of pressure and resistance to cause the movement of the piece of rock in a line more or less divergent from the line of motion of the glacier itself. The most common of the circumstances where this might occur, would be where an oblong fragment with a sharp edge has fallen to the



Scale 1 inch to a mile
Liverpool Bay
Bootle
New Brighton
Wallasey
Liscard
Egremont
Liverpool
Poulton
Seacombe
Mersey
River
Landing stage
Great Float
Bidston
St Saviours Ch
Bidston Hill
Birkenhead
Woodside
Christchurch
Tranmere
Happy Valley

base of the glacier in such a position that its long axis would lie rather obliquely in the direction of the flow of the glacier, in which case the direction of its long axis would be that of least resistance; and I think a groove diverging 25° from the direction of the current might very probably be formed in this manner, but this matter is one that is worth further investigation.

I am afraid I have not done anything to clear up the glacial question, but I have tried to lay before the Society a few facts that have come under my notice; and if I have been tempted to theorise, my excuse must be the hope, that by constantly varying the grouping of our facts and the light we throw upon them, we may in time get nearer a true solution of this question than we are at present.

Note.—The map shews the position and direction of striæ in the neighbourhood of the Poulton Quarry. The figures give the direction of the striæ in degrees W. of N. A short line crossing the other indicates cross striation; the figures only refer to the principal striation. For other striations beyond the limit of the map see "The Glacial Striæ of the Country around Liverpool," by G. H. Morton, F.G.S., Proc. L'pool Geol. Society, 1876-7.

BORINGS ON THE SOUTHPORT AND CHESHIRE LINES EXTENSION RAILWAY.

By T. Mellard Reade, C.E., F.G.S., &c.

This railway, commencing at Aintree, runs parallel to the East Lancashire Railway, passes between Maghull and Sefton, skirts the moss land of the River Alt, and entering the main moss land between Altcar and Haskayne, crosses the Downholland Brook near the centre of the moss, and afterwards the Liverpool and Southport

Railway some half-mile south of Ainsdale Station.

By the favour of Sir Charles T. Metcalfe, the resident Engineer of the line, I have been favoured with the records of the borings taken at various points along this line to prove the depth of the moss and superficial deposits with which they had to contend in building the piers of the bridges. The whole form an interesting section of a locality of which we had previously but imperfect information.

Commencing at the point where the line crosses the Liverpool and Southport Railway, and proceeding in reverse order to the description just given, the following are the records of the localities:—

BOREHOLE No. 20.

BY LIVERPOOL AND SOUTHPORT RAILWAY.

	FT.	IN.
Running sand (blown sand)............	18	0
Hard black peat	2	0
Black sand................................	1	0
	21	0

No. 19.

BY POOL'S LANE.

	FT.	IN.
Sand (blown)	15	0
Peat	5	0
Black sand.................................	7	0
	27	0

No. 18.

300 YARDS BEYOND NO. 19.

	FT.	IN.
Sand	2	0
Peat	16	0

Loam	9	0
Silt	8	0
	35	0

No. 17.

BY DOWNHOLLAND BROOK.

	FT.	IN.
Peat	12	0
Silt	26	0
Hard brown clay (Boulder-clay)	4	6
	42	6

No. 16.

BY MOSS LANE, 430 YARDS BEYOND NO. 17.

	FT.	IN.
Peat	11	0
Silt	11	0
Sand	3	0
Strong clay (Boulder-clay?)	8	0
Rock		
	33	0

No. 15.

870 YARDS BEYOND NO. 16.

	FT.	IN.
Peat	13	0
Sand	4	6
	17	6

No. 14.

100 YARDS BEYOND NO. 15.

	FT.	IN.
Peat	14	0
Sand	3	6
Clay (Boulder-clay?)	2	6

No. 13.

1,340 YARDS BEYOND NO. 14.

	FT.	IN.
Peat	2	6
Running sand		

Between No. 13 and Wood Lane, a distance of about 800 yards, the following bores were taken:—

No. 12.

	FT.	IN.
Peat		

No. 11.

Peat		

No. 10.

Peat	3	6
Loam		
Clay		

No. 9.

Soil	2	0
Clay		

No. 8.

Soil	2	0
Clay	3	6
Running sand		

No. 7.

BY WOOD LANE.

Peaty soil	2	9
Sand	1	0
Clay and sand	4	3
Rock		

This completes the section across the main moss land. It will be observed that the succession of the strata is, in ascending series, rock (Lower Keuper Sandstone) Boulder-clay, Sand (Washed Drift or Shirdley Hill Sand) Silt (Formby and Leasowe marine beds) Peat (Superior Peat and Forest bed), Sand (Blown Sand) from the shore.

The Blown Sand 18 feet deep and lying on the hard peat in the bore by the Liverpool, Crosby, and Southport Railway, thins off to 2 feet in a distance of about 1,300 yards. The peat in the same distance thickens from 2 feet to 5 feet. At Downholland Brook, the centre of the moss, the peat thickens to 12 feet, from which point it continues from 11 to 14 feet thick as far as Bore-hole No. 14. At Bore-hole No. 13 it thins again to 2 feet 6 inches. We are now approaching the inland margin of the moss land, and at Bore-hole No. 9 we get on to the soil lying upon the Boulder-clay.

It is a pity that Bore-hole No. 20 did not reach the Boulder-clay: we are therefore left in the dark as to the depth at which it lies at this point. The bore No. 17 by Downholland Brook, about 3,700 yards inland from the Liverpool, Crosby, and Southport Railway, gives the most westward indication of the Boulder-clay, at a depth of 38 feet below the surface of the moss. We cannot therefore tell whether the surface of the Boulder-clay is a basin of which this is apparently the deepest point, or whether it gradually shelves westwards towards the present coast-line.

No bores were made westward of the Liverpool, Crosby, and Southport Railway; the new line running through the sand dunes to Southport, where they were unnecessary. It will be observed that the sand below the silt (probably Washed Drift Sand) only occurs from

the inland margin to No. 16 bore for a distance of about 2,500 yards.

It is satisfactory to find that all the strata are in harmony with previous descriptions I have given in my "Post-Glacial Geology of Lancashire and Cheshire" (Proc. of L'pool Geo. Soc., 1871).

DEPOSITS IN THE ALT VALLEY.

I will now, commencing at a point where the line crosses the Leeds and Liverpool Canal and proceeds westwards, describe the bores made in the valley of the Alt:—

BORE-HOLE No. 1.

	FT.	IN.
Sandy soil	10	0
Clay (Boulder-clay)	8	0
	18	0

No. 2.

NEAR THE EAST LANCASHIRE RAILWAY, AND 180 YARDS FROM NO. 1.

	FT.	IN.
Sand	8	0
Clay (Boulder-clay)	4	0

No. 3.

300 YARDS FROM NO. 2, AND NEAR THE EAST LANCASHIRE RAILWAY.

	FT.	IN.
Sandy soil	12	0
Clay (Boulder-clay)	4	0

No. 4.

BY MILL DAM.

Sand	24	6
Clay (Boulder-clay)	4	0

No. 5.

BY RIVER ALT.

Sand	20	0
Clay (Boulder-clay)	4	0

No. 6.

BY SEFTON LANE.

Sand	24	6
Clay (Boulder-clay)	5	6

The distance from Bore-hole No. 1 to Bore-hole No. 6 is over 3,000 yards. No peat appears to have been met with. The sand may be seen in the new cut ditches by Sefton Station, the top layer bleached nearly white, and a brown, soily-looking layer underneath. It is quartzose and undoubtedly a continuation of the Washed Drift Sand found in the Alt Valley between Clock House Bridge and Alder's Bridge, on the Walton Sewage Farm at Fazakerley, and also about Aintree.*

The Section as a whole is interesting as further extending our knowledge of the lie of the Post-glacial beds of our neighbourhood, which are, in a physical point of view, second to none in geological interest.

* See "Post-Glacial Geology of Lancashire and Cheshire," p. 15.

ON A SECTION ACROSS THE RIVER DOUGLAS AT HESKETH BANK.—A POST-GLACIAL DEPOSIT IN WHICH WERE HUMAN BONES.

By T. Mellard Reade, C.E., F.G.S.

In September, 1881, I visited the site of the bridge of the West Lancashire Railway thrown across the Douglas at Hesketh Bank, between Southport and Preston. The girders of the bridge rest upon iron cylinders, which are sunk through Post-glacial deposits to the Boulder-clay. The special interest of the section lay in the fact that in the foundations of one of these piers human bones were said to have been discovered; and to see these and to find out under what conditions they had been buried, was the principal object of my visit. The site of the bridge lies in the area of the map accompanying my "Post-glacial Geology of Lancashire and Cheshire" (Proc. L'pool Geo. Soc., 1871), and is colored green, representing "Recent Silts," and lying between banks of Boulder-clay. The Boulder-clay at Hesketh Bank rises to a height of 50 feet above Ordnance Datum, and it has by the combined influence of the tide and river, been cut into steep cliffs before the reclamation of the present marsh, which has been carried out since the 6 in. Ordnance map was surveyed. The west piers of the bridge rest directly on the Boulder-clay; the iron piers are on the east bank, and beyond this, on the Much Hoole Marsh, the piers are of brick, on pile foundations. The human bones which I saw consist of right and left thigh bones (*femora*) 16 inches long, one of them having been broken in getting it out. The cylinders were sunk by weighting them and excavating from the inside, and the edge of the cylinder is

supposed to have severed the broken bone. There were also the *fibula* and two portions of the *pelvis*, containing the sockets (*acetabulum*). I tried to induce the contractor, Mr. Jas. Blackburn, to whom I am indebted for these particulars, to present the bones to our museum, but failed, and do not know what has now become of them. The level at which the bones occurred was 20 feet below the surface of the marsh, at that point about flood level, so that they lay somewhere about Ordnance Datum. In some of the other cylinder excavations animal bones were found. Mr. Blackburn stated that the silt smelt very badly while being excavated, and this it commonly does, I know by experience.

The section of the strata penetrated by the cylinders was as follows:—

SECTION AT A IN DIAGRAM.

	FT.	IN.
Yellow sand	9	4
Wet dark grey sand	6	3
Ditto, mixed with shells	3	1
Wet dark grey sand, with pieces of oak timber	2	0
LEVEL AT WHICH THE HUMAN BONES WERE FOUND.		
Very stony coarse gravel, composed of limestone mixed with wet blue sand, a little clayey	3	4
Soft red clay	0	8
	24	8

Below this was hard red Boulder-clay.

The gravel appeared to be, from the description given to me, shingle derived from the Boulder-clay, mixed with a few large boulders.

The bones were heavy, as is usual with them when occurring in silt—I suppose from the infiltration of iron oxide.

As the recent silts are so very similar to those underlying the Superior Peat and Forest-bed (Formby and Leasowe marine-beds), it is often difficult to determine to which age a deposit belongs. I am inclined to place the bones as posterior to the main peat, and in that case the whole of the deposits penetrated to this depth would have to be classed as recent. The pieces of oak timber found near them have probably been derived from the destruction of the peat bed, and the deposit may be considered to be estuarine silt overlain by shore sand. Unfortunately, as is generally the case in such finds, it is difficult to put down any actual age in years to these bones; but evidently they must be of considerable age, because, even if we assume that they were deposited in the bed of the Douglas and by a slight change in its windings they became buried, yet the presence above them of a bed of marine shells seems to show that the conditions were different then to what they are now. I do not think that any marine shells would be found in the silt at the bottom of the present river. It will also be observed that the bones lay very close to the top of the "very coarse gravel" forming the bottom stratum of the Post-glacial deposits. These gravels must have been laid down by the river when its bed was higher with respect to the sea-level than now, for nowhere on the coast are gravels being laid down in such situations at similar levels. It is therefore probable that this relic of ancient man is of an age long prior to the Roman occupation, as there is no evidence of an appreciable alteration of levels since Roman times.* I have elsewhere attempted to shew that the blown sand of our coast has taken not less (and probably much more) than 2,500 years to accumulate, and that no change of level has taken place

* "Post-Glacial Geology of Lancashire and Cheshire."—Proc. of L'pool Geo. Soc., Session 1871-2, p. 76.

in that period.* Unfortunately there is always some element of uncertainty in these calculations; but that the remains are those of "early man" we may fairly consider. We cannot, however, put this individual as contemporary with the mammoth, as no remains of extinct animals have ever been found in this series of Post-glacial deposits.

Before closing my remarks, I would draw attention to the recent work of Sir Richard Owen "On the Antiquity of Man, as deduced from the human skeleton found in the excavations of the Tilbury docks." Fortunately in this case, the proof that the individual lived prior to the last change of level is complete, as the skeleton was found at a depth of 33 feet below the marsh level, with several layers of peat at different horizons above it; this peat could not have grown at the present relative levels of land and water. The remains were actually in the sand overlying the bottom or ballast gravel, and the evidences of antiquity in this case were of the most satisfactory and convincing character. The overlying deposits agree very closely with the sands, muds, peats and silts, making up much of the Post-glacial beds of Lancashire and Cheshire.

If my reasoning in the foregoing remarks is valid, the remains found at Hesketh Bank are those of an individual who lived before the last change of level was completed, and the whole of the overlying deposits and the extensive marsh extending out seawards but now reclaimed, have been since laid down; the evidence of antiquity, though not nearly so complete as that of the Tilbury skeleton, is still substantially better than in any other recorded find in this district.

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* "The date of the last Change of Level in Lancashire."—Q.J.G.S., 1881, p. 436–9.

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* Have read Papers before the Society.

† Contribute annually to the Printing Fund.

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PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTY-SEVENTH.

1885-6.

EDITED BY W. HEWITT, B.Sc.

(*The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.*)

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PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-SEVENTH.

OCTOBER 13TH, 1885.

THE PRESIDENT, T. MELLARD READE, C.E., F.G.S., in the Chair.

The Officers and Council for the ensuing year were elected.

The President then read his Annual Address :—

THE NORTH ATLANTIC AS A GEOLOGICAL BASIN.

NOVEMBER 11TH, 1885.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair.

The Treasurer read his Annual Report, which had been duly audited.

Mr. EDMUND DICKSON, Mr. JOSEPH LOMAS, Rev. B. LEWORTHY, Mr. CHARLES C. MOORE, Mr. THOMAS S. KEYTE, C.E., and Mr. WILLIAM WRENNALL, were elected Ordinary Members of the Society.

The following papers were read :—

ON A BASALTIC DYKE AT BEITH, NEAR GLASGOW,

AND

FURTHER NOTES ON A PEGMATITE VEIN IN GRANITE QUARRY AT RUBISLAW, NEAR ABERDEEN.

BY G. H. MORTON, F.G.S.

THE OCCURRENCE OF BITUMEN IN THE PALÆOZOIC ROCKS OF SHROPSHIRE.

By C. Ricketts, M.D., F.G.S.

DECEMBER 8th, 1885.

The President, G. H. MORTON, F.G.S., in the Chair.

Mr Thomas Goffey and Mr. A. Norman Tate, F.I.C., were elected Ordinary Members of the Society.

The following papers were read :—

ON A SECTION OF THE UPPER KEUPER AT OXTON.

By H. C. Beasley.

NOTES ON A BED OF FRESHWATER SHELLS AND A CHIPPED FLINT LATELY FOUND AT THE ALT MOUTH.

By T. Mellard Reade, C.E., F.G.S.

JANUARY 12th, 1886.

The President, G. H. MORTON, F.G.S., in the Chair.

The following papers were read :—

ON THE OCCURRENCE OF COPPER IN THE KEUPER OF THE PECKFORTON HILLS.

By Osmund W. Jeffs.

NOTES ON THE TOPOGRAPHY OF LIVERPOOL.

By W. Hewitt, B.Sc.

FEBRUARY 9th, 1886.

The President, G. H. MORTON, F.G.S., in the Chair.

The following papers were read :—

A VISIT TO THE "COPROLITE" DIGGINGS IN THE CAMBRIDGE GREENSAND.

By H. C. Beasley.

BOULDERS WEDGED IN THE FALLS OF THE CYNFAEL.

By T. Mellard Reade, C.E., F.G.S.

ON A SECTION OF THE TRIAS AT VYRNWY STREET, EVERTON, DISPLAYING EVIDENCE OF LATERAL PRESSURE.

By T. Mellard Reade, C.E., F.G.S.

MARCH 9th, 1886.

The President, G. H. MORTON, F.G.S., in the Chair.

The following paper was read :—

THE ORIGIN OF PETROLEUM AND OTHER NATURAL HYDROCARBONS.

By A. Norman Tate, F.I.C.

APRIL 13th, 1886.

The President, G. H. MORTON, F.G.S., in the Chair.

Mr. W. D. H. Deane, M.A., was elected an Ordinary Member of the Society.

The following paper was read :—

IMPRESSIONS OF FOOTPRINTS AND PLANTS FROM THE TRIAS AT OXTON HEATH.

By C. Ricketts, M.D., F.G.S.

THE NORTH ATLANTIC
AS A
GEOLOGICAL BASIN.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

Continuing the line of investigation sketched out in my last address,* I propose to consider in what way the enormous amount of mineral matter annually poured into the Atlantic Ocean is distributed. Deposition is the first stage in the reconstruction and renovation of the earth's crust, as denudation is the last stage in its destruction.

It follows that if we can glean anything like accurate ideas of these two great and complementary processes of nature, we shall have advanced a step towards a solution of many of the great and still unsolved problems which the geological history of our earth presents to curious and enquiring minds.

It is well to admit at once that the enquiry presents many difficulties, chiefly arising from the fact that the great bulk of the deposits are entirely out of view, and our only direct knowledge of their nature and distribution is limited to superficial dredgings in various depths of water. Still the science of Geology has advanced sufficiently to enable us in many cases to say what amount of matter has been removed from a given area within a given geological time with some approximation

* "Denudation of the Two Americas."—Proc. of L'pool Geo. Soc., 1884–5.

to truth, while the rocks themselves bear witness to the conditions under which they have accumulated and the manner in which they have been built up. It is by piecing together more or less connected facts and mentally putting them in relation to each other that we may be enabled to penetrate some of the mysteries of nature which cannot be attacked in a more direct manner.

Before entering upon the question of sedimentary distribution, it will be necessary to glance at what is known of the form of the ocean bottom. It is only of late years that anything has been accurately ascertained repecting even its depth. There was a general idea prevalent that the depths of the great oceans much exceeded what is now known to be the truth. Still the information is yet so extremely limited, that we should pause before attempting generalisations from what little we know, and still more from surmises respecting those parts of which we have no accurate information.

Through the enormous traffic which now crosses the North Atlantic, the soundings taken in connection with the oceanic cables, the continental coast cables, the soundings and dredgings of the "Porcupine," "Challenger" and "Talisman," the United States Coast Surveys and investigations of the Fish Commission, and the surveys of our own navy, more is known of the form of the North Atlantic basin than of any other oceanic area. By the kindness of Sir James Anderson, the eminent telegraph engineer, I am enabled to lay before you a map of the Atlantic between the equator and 60° N. latitude, with contours of the bottom approximately marked thereon, in stages of 500 fathoms. No doubt much of this is inference, and we must bear that in mind while embodying our opinions.

It will be observed on studying this map that the portions enclosed by the 3,000 fathom contours are small in relation to the entire area of the oceanic waters represented. The 3,500 fathom contour encloses a very limited area situated in lat. 27° N., and long. 60° W., and another nearer to the Antilles. It is also noticeable that the contour lines approach one another as the continental coasts are neared. Not less remarkable is the fact that an area of depression below the 2,500 fathom contour exists in the Bay of Biscay some 60 miles from the N. coast of Spain and 200 from the S.W. coast of France.* The 2,000 fathom contour connects Madeira, the Canaries, and the Cape de Verde Islands with the African mainland, while on the opposite or E. coast of America no outlying islands exist. The 2,500 fathom contour runs close to the Antilles or Bahama Islands, and follows the American coast pretty closely as far north as Newfoundland, when it returns south again. The West Indian Islands, the Carribean Sea, and the Gulf of Mexico are cut off from the deeper portions of the Atlantic by the 500 fathom contour, although there is a large area—55,000 square miles—in the Gulf of Mexico† below the 2,000 fathom contour. The Medi-

*The following is extracted from the *Engineer*, November 27th, 1885, page 421:—"Direct Spanish Telegraph Company's Cable, between Kennack Cove, Cornwall, and Bilbao, Spain, broke down on the 11th of October, 1885, and was repaired by the Eastern Telegraph Company's steamer 'Electra' on the 9th November. The repairs were effected in three working days, although the depth of water was 2,300 fathoms, or more than 2½ miles. Only three drags were made for the cable, it being caught and lifted in each case, but in the first haul the cable broke in the grapnel, the ship being a little too far from the broken end. Another cable, between Otranto and Corfu, laid 24 years ago, was raised from the botom in 560 fathoms and repaired."

† J. E. Hilgard—"Basin of the Gulf of Mexico."—Amer. Jour. of Science, vol. xxi., p. 290 (1881).

terranean is a repetition of the same conditions on the old continent, being a deep basin with only shallow communication with the Atlantic.

The Azores are situated upon a central area connecting the N. coast of South America with Iceland, and enclosed by the 2,000 fathom contour. It is of this area that we want much fuller information. It will be observed that on the route of the Anglo-American cable of 1880 there are marked a series of small depressions below the 2,000 fathom contour; while on the Jay Gould line there is an elevation with only 700 fathoms of water above it—lat. 50° N., long. 29° W. On the "Anglo," 1869, there is an elevation with 1,130 fathoms over it, in lat. 48° N., long. 29° W. In lat. 42° 30′ N., long. 29° W.—I give the positions only roughly from the chart—there is an elevation rising to within 48 fathoms of the surface. In lat. 28° N., long. 40° 20′ W., there is a sounding of 600 fathoms. Between the latter and the Azores, a distance of 1,000 miles, there are no soundings on the chart.

It would appear from these examples that there is a ridge about long. 29° W. running N. and S. for a considerable distance through 10 degrees of latitude, and it is extremely probable that it is connected with the sounding last given 1,000 miles to the S.W. of the Azores. It is also a noticeable fact that the closer the soundings are together the more striking are the inequalities of the bottom, which of itself should make us cautious in assuming that the bottom of the ocean is a level plain because a couple or so of soundings very far apart do not differ much in depth. The late Mr. Gwyn Jeffreys has stated*—"While repairing, in 1878, the Anglo-American cable, a tract of rocky ground was discovered

* *Nature*, Feb. 3, 1881, p. 325.

about 100 miles in length in the middle of the N. Atlantic, between 33° 50′ and 36° 30′ W. longitude, and about 51° 20′ N. latitude. Within a distance of 8 miles the shallowest sounding was 1,370 and the deepest 2,230 fathoms, a difference of 860 fathoms, or 5,160 feet; within 4 miles the difference was 3,180 feet, and within half a mile 1,380 feet. There are also the Laura Ethel Bank with a depth of only 36 fathoms, and the Milne Bank with 81 fathoms, both about 550 miles from Newfoundland, which is the nearest continental land. Other instances are the Josephine Bank with 82 fathoms, and Gettysburg with 30 fathoms; the distance of the former from Cape St. Vincent being 250 and the latter 130 miles, with intermediate depths of 1,700 to 2,500 fathoms."

Nearer the coasts the inequalities of the bottom are very considerable. Sir James Anderson informs me that they "find very great inequalities in the bottom from Lisbon towards the Canary Islands. Off the Burlings we found a crater nearly 1,000 fathoms deep, into which the cable ran, and we had afterwards to recover and re-lay it. On the top of the crater we found 80 fathom soundings." In reply to further queries Sir James says: "As to the sudden increase of depth off the Burlings, I should call it a crater and not a depression, as it is only a few miles in diameter. All round it is under 100 fathoms, while the cavity is 1,000 fathoms." "As for valleys, they are abominably abundant and very precipitous." "For example: off the Burlings, lat. 39° 25′ 30″, long. 9° 54′ 00″, the ship had 1,300 fathoms under her bow, and sounding under the stern they got 800 fathoms. Off Lisbon and up the edge of the soundings there are great inequalities, which no doubt are

a chain of mountains in the ocean. The problem we have to solve when the cable is laid over such places, is by numerous soundings to trace out the valleys. Sometimes we succeed, but sometimes we do not, as often within half a mile there are great inequalities, and it would be impossible to sound the whole ocean every half-mile."

Thus by the evidence of practical men, on whom devolves considerable responsibility for the success and maintenance of the great sea cables, we are further strengthened in the opinion that the ocean bottom is full of inequalities, contrary to the recent dicta of some scientific theorists who regard the ocean bottom wholly as an extended plain sloping, and that not rapidly, at the borders towards the continental shore lines. The more it is found necessary to sound the ocean, the more apparent, I am convinced, will these inequalities become. A very good example of the truth of this remark has just come to hand, as Prof. Verrill, describing the work of the U.S. steamer "Albatross" in 1884,* says that five stations in depths below 2,000 fathoms were between N. lat. 36° 05′ 30″ and 37° 48′ 30″, and between W. long. 68° 21′ and 71° 55°, while the chart shews a sounding immediately north of this area of 250 fathoms.

Having now glanced at some of the characteristic features of the North Atlantic Ocean bottom, it will be necessary to direct our attention to the rivers delivering into it, and in order to further extend our enquiry, we may assume that the South Atlantic is only an extension of the same basin, and that its main features do not radically differ from those of the North Atlantic. To simplify the enquiry, we will confine our attention to the

* Amer. Jour. of Science, Nov. 1884, p. 378.

greater continental rivers, those I treated of in my last address, viz., the St. Lawrence, the Mississippi, the Amazons, and the La Plata on the American continents, and the Congo on the African continent, with perhaps a glance at others elsewhere as the exigency of illustration demands. One of the most striking facts connected with those great rivers whose embouchures have been tested by borings, is the great depth of deposit that has to be penetrated before the original bed of the river is reached. In the case of the Mississippi it is not less than 630 feet below the sea level.* Unfortunately I know of no borings in the St. Lawrence, the Amazons, or the other rivers named, but it is more than inferentially probable that their original beds are much depressed. The forms of the mouths of the La Plata and the St. Lawrence are better explained by subsidence than by any other hypothesis. But not only is the original bed of the Mississippi much depressed, but the grade of the river valley is so low now that to bring it back as a working river to its original condition it would appear to require a general elevation of a large part of North America. If we do not adopt this view, the alternative seems to be that an enormous thickness of rock has been worn off its basin at an extraordinary low inclination? † Taken in connection with earth movements as shown elsewhere, it would appear that a general, as well as differential, subsidence is the readiest and the most reasonable explanation of its present condition. The ancient beds of most rivers are proved in many cases by borings not to possess a regular grade, but to be in

* Professor Hilgard, Messrs. Humphrey and Abbott's Report.

† Professor J. W. Spencer thinks there is proof of a former elevation of the whole Mississippi valley of 3,000 feet. "The Mississippi River during the Great River Age," page 5.

what we may call wave lines, which is doubtless the result of differential subsidence.*

A boring in the old alluvium of the Narbada at Súkakheri, far from its mouth, shews a depth of 491 feet of alluvial deposits, finishing in lateritic gravel without the bed rock being reached.† It is also a pretty general if not universal rule that the lower deposits in river beds are the coarser, consisting of gravel, shingle, or boulders. This is true of the Ganges as well as of the Mississippi, and it is a pretty good evidence of a superior grade in former times, which again means subsidence by earth movements. Dr. G. M. Dawson has lately been led to infer from the position of certain Lawrentian boulders in Canada, 700 miles from and over 2,000 feet above their origin, that the East coast was formerly higher in relation to the interior.‡ It is pretty generally considered by American geologists that there have been earth movements about the great lakes which have diverted the course of their outflows into other channels; and Gen. G. F. Warren is of opinion that the drainage of Lake Winnipeg was formerly along the Minnesota and Mississippi, and considers that the buried river channels met with in that district are due to alternate elevations and depressions.§ Facts of a similar nature pointing to differential movements of the continental lands upward or downwards, as the case may be, might be multiplied

* Professor J. W. Spencer points out that the pre-glacial channel of the Mississippi has now a less slope than the modern surface, "being respectively about 0·45 and 0·70 of a foot per mile along a direct line." "The Mississippi River during the Great River Age," p. 6., Reprint.

† Manual of the Geology of India, p. 384.

‡ Geo. Sur. of Canada.—Report of Progress, 1882-3-4, p. 149 c.

§ Valley of the "Minnesota and Mississippi Rivers," Engineer Dept., U. S. Army.

had I time, but I think I have given sufficient examples to indicate my meaning.

The foregoing facts might perhaps be held to invalidate the view that the main river channels of continents are of great antiquity. Rightly considered, I hardly thnk they do. The enormous mass of matter which it can be proved has been worn out in many cases to form the valley is of itself a proof of antiquity. No doubt the levels undergo great changes, and the conditions of the basins also suffer a correlative change, but there appears a tendency to revert to the original lines of drainage. A great depression worn into a continent cannot be got rid of except by a breaking up of the strata; and even this, when the grade is steep, does not always obliterate the river course. Captain Dutton has graphically shewn that the degraded matter, of from 6,000 to 10,000 feet of strata, occupying an area of 10,000 square miles, has all passed down the Colorado to the Pacific, and this in spite of frequent upthrows on its course from Tertiary times until now.*

The Amazons basin is largely filled with Tertiary riverine deposits, which it is now clearing out and carrying to the sea. There are Tertiary deposits in the basin of the Rhine.† In every large river there exist undoubted evidences of antiquity, but to trace out the history of a great river system is a very perplexing problem in physical geology. Still the fact of the existence of a great river system is an *a-priori* proof of geological antiquity. There are certain permanent features of the earth's surface which no amount of subsidence or elevation seems to affect. Mountain

* Geology of the High Plateaus of Utah, p. p. 15-20,

† Belt. "The Loess of the Rhine and Danube."—Quarterly Journal of Science, p. 17 of Reprint, January, 1877.

ranges once formed remain mountain ranges until effaced by denudation or covered up by deposit. The mountains of North Wales, formed in Silurian times, remain mountains still. The Pennine chain of Carboniferous age is not yet effaced, though part of a range of similar age is supposed to extend under London and join the Belgian coal fields with the Mendips. In many cases where rivers are supposed to have preserved their course notwithstanding the elevation of mountain chains across their channels, I am inclined to take another view, and attribute it to the wearing down and backwards of the river channel, which initially flowed at a higher level than the ridge it crosses. Mountain chains must be considered to be permanent reliefs in the continental maps, and river channels less permanent, but still lasting marks of Nature's graving tools. It is evident on a little consideration, that mountains and hills must have a great effect in fixing the direction of a river channel, and once it is deeply cut into a continent, differential subsidences will not readily obliterate it or materially change its direction. If we admit, what I think can hardly be disputed, that great rivers are of enormous antiquity, we may well ask ourselves what has become of the material ceaselessly washed down into the sea with almost the regularity of time itself? We see that the valley of the Amazons was a valley in Tertiary times; and although there have been fluctuations of level in the continent of South America, as shown by Darwin, the Andes must have formed the "great divide" between the Pacific and the Atlantic ever since the initial stage of elevation. It follows, therefore, that whether the Amazons, the La Plata, and the Orinoco have been absolutely permanent drainage lines or not, the material

of the continent, whatever its form, must have flowed into the Atlantic Ocean. The Andes, according to Darwin, were founded, if I may use the term, in Cretaceous times; it follows that since then the ruins of these mountains must have gone partly to form deposits on the continent of South America, but mainly into the Atlantic Ocean.

An examination of the Atlantic chart shews what appears to be a prolongation of the American continents into the ocean in a bench of varying width following the coast line, at the edge of which a more rapid depression takes place. It is usual to look upon these benches as wholly composed of the solid rocks of the continent. It is quite as legitimate to assume that in many cases they are largely composed of sedimentary matter degraded from the continental lands. The soundings at the mouths of the Amazons for a distance of 60 miles rarely exceed 10 fathoms, and are in some cases not more than 5 fathoms, and for as far as 150 miles from the coast do not exceed 45 fathoms. It is certainly probable that this is due to a levelling up of the ocean bed, which, whatever its depth may have been, is only a question of time. At all events it would be difficult to find a belt of land with such slight inequalities as is exhibited by the submarine plateau, extending in the front and to the north and south of the Amazons' mouths. We know there have been strata of many miles in the thickness laid down in former geological periods without apparent break or unconformity. Nature is uniform in her action, and there is no reason that I know of to assume that these operations have ceased. If not, then where are thick deposits more likely to be taking place than on coasts near the mouths of rivers draining areas that have to be measured by millions of

square miles? Whatever the form of the bottom or depth of water into which the river delivers its burden, it will in time shallow it. The sea thus acts as a leveller, spreading out the deposits to a uniform depth —cutting off here and laying down there. These continental benches are in my view the true submarine plains—plains of denudation as well as deposit.

The soundings off the South American coast in the neighbourhood of the Amazons shew a pretty uniform distribution of "grey sand with black specks," occasionally mixed with broken shells. There are also some banks of mud and sand and hard mud; but according to the chart of the entrances to the Amazons I exhibit, grey sand mostly prevails. There do not appear to be any rocks—in fact it is just the sort of deposit, judging by its extension and uniformity, we should expect to be of great thickness. This is, of course, and can be, only an inference; but if we believe in the antiquity of continents, if it be but from the Tertiary period downwards, the inference is a legitimate one. There is, of course, the possibility to be taken into account of the former extension seawards of the continent, such as would be caused by the fluctuating depressions and elevations referred to at the commencement of this address. Such fluctuations would have the effect of spreading the deposits over a larger area, but probably would not affect their distribution to the extent that we might at first suppose. I am sensible that in opposition to this "levelling up" theory, the phenomenon of the "Swatch of no ground" opposite the mouth of the Ganges may be pointed to; but, as far as I know, it is a special submarine feature that does not appear in connection with any other great river. It would be, therefore, unfair to argue from an exceptional physical feature, for such

exceptions meet us everywhere in geology. It may be due to bottom currents, or to recent geological subsidence.*

The New Orleans boring penetrated deposits to a depth of 630 feet below the surface. Prof. Hilgard is of opinion that the river silt does not exceed 108 feet, and the remainder of the deposits are marine, not post-pliocene. It seems to me pretty evident that the Mississippi contributed the materials of which the deposits were made up; and it is a matter of little moment whether they were laid down as an alluvial delta or as a submarine extension of it. The controversy with Sir Charles Lyell as to the actual age of the delta seems to me to have been carried on without its bearings being clearly understood. The circumstance of the deposits of a river being fresh water, estuarine, or marine depends on the conditions of its embouchure. They may be any of these three. If the river delivers into deep water the deposits will be mostly marine until they level up the sea bottom, when they may change to estuarine, and again to river silt. The time occupied by these changes will be determined by several factors: the amount of sediment brought down annually, the depth of the sea into which they are delivered, the strength, set, and permanency of the sea or ocean currents, and the rate, range, and direction of the vertical movements that seem constantly taking place in the land and sea bottom, or the length of the pauses that have taken place in these movements.

In illustration of this, I may mention the boring at Calcutta, in the Ganges delta. Full details are given in

* Mr. Fergusson is of opinion "that the sediment is carried away from the spot, and deposition prevented by the strong currents engendered by a meeting of the tides from the east and west coasts of the Bay of Bengal."—Manual of the Geology of India, p. 408.

the Manual of the Geology of India, pp. 397–400. The bore was carried down to 460 feet below mean sea-level, ending in a fine sand intermingled with shingle, without the base of the delta being reached. The whole of these deposits, excepting possibly the last, were considered by Dr. Blanford to be of fresh water origin. At Umballa, between the Jumna and the Sutlej, a bore was put down in the Indo-Gangetic plain 701 feet, ending about 200 feet above the sea level, without penetrating to the base of the alluvial deposits. It is therefore evident that the Ganges valley, as far as penetrated, was levelled up by the alluvial deposits of the great river, at least as rapidly as the subsidence took place. It would appear from the New Orleans bore-hole that the subsidence of the valley of the Mississippi was too rapid in its first stages to be overtaken by the deposits the river brought down. Seeing that in these two last rivers the bed rock was not reached at such great depths at points inland of the shore lines, it is a fair and probable inference that outside and seawards the deposits are in most cases enormously thicker.

The lower deposits penetrated at New Orleans were considered by some to be pliocene, and even miocene. I agree with Prof. Hilgard that they are post-pliocene, but the fact that this difference of opinion should occur is a pretty good proof of *age;* and if, as we may legitimately infer, the Mississippi laid down the materials of which the deposits are composed, or we even account for them in any way by continental denudation, we must be prepared to admit also that the deposits overlying the rocky floor of the sea at their mouths, and which may be considered as geologically modern, are of very great thickness.

In investigating the nature and extension of oceanic sedimentation, we must not neglect the possible exist-

ence of submarine currents. Sir James Anderson says, in a letter to me—"Perhaps the most marked experience we have had of currents at great depths was in the case of the Falmouth cable, near Gibraltar. At 500 fathoms the wire was ground like the edge of a razor, and we had to abandon it and lay a new cable well in shore. Captain Nares, of the surveying ship 'Nemesis,' I think, with tangles could get no specimen of the bottom whatever, and he thinks he got sufficient evidence to prove the existence of a perfect swirl at that depth." Again we have it on the evidence of Prof. Verrill that the deposits under the Gulf Stream, even at great depths, do not correspond with the "Challenger" experiences. Large blocks of sandy clay were brought up from 1,060 fathoms, and large masses of hard but sticky greenish blue clay from 1,168 fathoms, and between 2,000 and 3,000 fathoms in all the 10 localities "Globigerina Ooze" occurred. The Red clay distinguishing such depths, according to the "Challenger" investigations, was not once met with.*

According to the late M. Milne Edwards, the "Talisman" soundings showed the bottom of the Sargassum Sea to be formed of "a thick layer of a very fine mud of a pumice nature, covering fragments of pumice and volcanic rocks." Between the Azores and France the sea bed "is carpeted throughout this region with a thick white mud composed almost exclusively of Globigerinæ, and covering pumice deposits and fragments of various kinds of rocks. Some of these rocks brought up in our nets bore the impress of fossils, amongst others of Trilobites. But what more surprised us was to find, at a distance of over 700 miles

* Marine Fauna and Deep-Sea Déposits off the Southern Coast of New England.—Amer. Jour. of Science, Nov., 1884.

from the European coast, pebbles polished and striated by the action of ice." The sea bed stretching westward of Morocco and the Sahara was found to be "extremely uniform, no longer presenting those rugged reliefs that had so impeded our operations on the coast of Spain."* Prof. Sars says the extensive depression between Norway, the Faroe Islands, and Iceland appears everywhere below 1,000 fathoms "to consist of a very peculiar loose, but very adhesive, exceedingly light, nearly greyish white clay, which is very strongly calcareous, and on being washed or passed through a sieve, appears to consist almost exclusively of shells of a little low organism belonging to the Foraminifera Biloculina." "The Biloculina clay of the cold area contains a greater quantity of lime than the Globigerina clay of the Atlantic.† At a distance of from 70 to 140 English miles from the coast of Norway, at the edge of the submarine barrier, in depths of from 300 to 100 fathoms, the bottom is generally hard and stony." "Numerous rolled stones, whose smooth rounded forms and worn edges clearly enough shew that they had at one time been subjected to the powerful action of ice, lie here strewn on the sometimes very uneven bottom, consisting of solid rock, and prevent the dredge from acting properly."‡ This submarine platform as a rule rises somewhat towards its outer edge before it slopes towards the great depths lying beyond it, and simultaneously assumes, as in the well-known case of the Storegg, a hard, stony character. "At the first sounding, when we went out from Husoe,

* The "Talisman" Expedition.—*Nature*, Dec. 27, 1883.

† Mr. Gwyn Jeffreys says the "Porcupine" dredgings gave from 50 to 60 per cent. ot carbonate of lime.—*Nature*, Feb. 3, 1881, p. 326.

‡ The Norwegian North Sea Expedition of 1876.—*Nature*, March 8, 1877, p. 412, vol. xv.

we struck this edge at about 140 English miles distance from the coast. The bottom, which before had everywhere appeared to be soft, suddenly at a depth of 221 fathoms became hard and stony, and retained this character even after it had sloped about 50 fathoms down towards the deep sea lying beyond."*

The difference in the nature of the submarine plateau off the coast of Norway and the belt of shallow soundings off the mouth of the Amazons, and which shallow belts more or less distinguish several of the coast lines of continents, especially near the mouths of great rivers, appears to be that the former is a submarine extension of the continental framework of the land, while the latter is the effect of accumulated sediment. The deeply serrated coast line of Norway indicates a considerable subsidence, for these great fjords, profound in depth, running up miles into the heart of the land, have undoubtedly been formed by the denudation of subaerial agents at a level much above the sea line. Under these circumstances we find the rugged nature of the country continuing far seawards under the rolling waves of the Atlantic. In the case of great continental rivers discharging into the open ocean or deep seas, the soundings are shallower and comparatively regular up to the edge of the great oceanic slope.

In conclusion, I am pretty well convinced from the reasons already given, namely, the great age and permanency of the river basins—such as the Amazons, which has certainly existed since Tertiary times—the depth of alluvial and other modern deposits at the mouths of most great rivers, the existence of extensive platforms about their mouths with uniform shallow water over them, the absence of rocks and presence of

* Ibid.—*Nature*, Vol. xv., p. 436.

modern sediments, that deposits are now taking place in the sea thousands of feet thick, and parallel to those, we know, have occurred over and over again in geological history. These deposits are, in my view, submarine extensions of the true deltas, which will make themselves felt in future geological history.

These considerations open up many geological questions of surpassing interest, of which we have hardly yet touched the fringe. The further we penetrate the unexplored regions of physical geology the larger appears the extent of country before us. Deeply sensible as I am of the slight and imperfect character of the sketch presented to you to-night, I trust that it may not be entirely barren, but may be found to contain some ideas that will germinate and yield further fruit.

ON BITUMEN IN THE PALÆOZOIC ROCKS OF SHROPSHIRE.

By Charles Ricketts, M.D., F.G.S.

After the field-meeting held last summer in the neighbourhood of the Wrekin, several members, under the guidance of Dr. Callaway, F.G.S., visited Haughmond Hill. Approaching it from Upton Magna Station, the party entered a quarry situated at its base, near Downton. It was found to consist of Longmynd shales and slate, full of small shrinkage joints; the rock being broken up into small pieces, with each of the crevices thus formed filled with mineral pitch.

At Nills Hill, Pontesbury, the quartzite band, forming the northern extremity of the Stiper Stone range, contains many cracks and fissures, small cavities,

and interstices between quartz pebbles in bands of conglomerate, filled with a similar substance.

In the calcite derived from the mineral veins in the Bog Mine, Shelve, instances have been observed of the interstices between the crystals being filled with bituminous matter.

Sir R. I. Murchison directed attention to the exudation of bitumen from the rocks at Haughmond Hill and likewise at Pitchford, considering that "if these substances were formed out of vegetable or animal matter, we can refer to seaweeds or minute worms only as the sources of them." * He appears to have entirely overlooked the character of the strata with which these rocks are associated. Coal-measure strata overlying Longmynd rocks occur about a quarter of a mile S.W. of the quarry in Haughmond Hill; the small area of Longmynd strata at Pitchford is entirely surrounded by Coal-measures. Coal pits exist at Pontesbury, a quarter of a mile northward of the Stiper Stone quartzite of Nills Hill; and the same locality is within five miles of the Bog Mine, which is also only seven miles from Le Botwood, a Coal-measure district to the east of the Stiper Stones. With the near proximity of coal in each of these localities, and the extreme probability that Coal-measures once extended over the whole, it is requisite to consider whether the cracks and fissures found in the rocks were formed before the Carboniferous strata were deposited; also the probability of the bitumen being derived from the decomposition of the vegetable matter contained in the coal strata once situated above them, but which have been removed by denudation, from which it percolated through the strata to the fissures before alluded to.

* "Siluria," Third Edition, p. 25.

Professor Jukes has demonstrated that the land where these localities are situated was never submerged during the period when the Carboniferous Limestone was being deposited.* It formed part of an isthmus separating the northern from the southern Carboniferous sea. During this period an amount of exposure to atmospheric vicissitudes must have occurred sufficient to account for any amount of fissuring. This land was subsequently pressed down by the deltal accumulations represented by the Coal-measures, subsiding in consequence of and in accordance with, their weight.†

Petroleum and other products from the decomposition of vegetable materials are recorded by Professor J. Prestwich ‡ and others as having been procured from the Coal-measures of Shropshire in such quantity as to be employed for commercial purposes. They have also been obtained from Coal-measures in other localities—Derbyshire, North Wales, &c.

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* "Memoirs of the Geological Survey—South Staffordshire Coalfield;" p. 13.

† "On Accumulation and Denudation, and their influence in causing Oscillation of the Earth's Crust." By Charles Ricketts.—Geol. Mag., Dec. 2, Vol. x., July and August, 1883.

‡ "Geology of Coalbrookdale."—Proc. Geol. Soc., Vol. ii., p. 403.

A SECTION OF THE UPPER KEUPER BEDS RECENTLY EXPOSED AT OXTON.

By H. C. Beasley.

This section was recently exposed in the cutting for a sewer close to where "Well Lane" is marked on the 6-inch Ordnance Map (Sheet No. 13, Cheshire), running from Wellington Road (182 feet above Ord. datum), just east of St. Saviour's Church, Oxton, to Shrewsbury Road South, in a slightly curved line with a general direction a little north of east, about 70 or 80 yards being exposed at the time I saw it.

The following was the section at Wellington Road:—

	FT.	IN.
Surface soil and red sand	1	0
Grey marly shale	2	0
Red shale, base not shewn, but about 4 feet exposed.		

The grey shales consisted of thin beds of soft sandstone alternating with thin beds of marly clay. Pseudomorphs of salt, dendritic markings, and ripple marks were very frequent throughout. This bed was very strongly marked, and preserved a uniform thickness and general character, except that the proportion of marl and sandstone varied in different parts. At this point the lower 6 inches was much more argillaceous than the rest, as was also the case with the upper 6 inches of the bed of red shale on which it rested; but the junction of the two beds was distinctly marked by the difference in colour. The red shales consisted of a harder rock, the beds of sandstone were rather thicker, and the marl present in much smaller quantity. The rock was of a dark brownish red colour, the surfaces ripple marked, and there were some imperfect pseudomorphs of salt,

and it contained numerous small cavities of irregular shape from $\frac{1}{8}$ to $\frac{3}{4}$ of an inch in diameter.

About 50 or 60 yards from Wellington Road the section shewed:—

	FT.	IN.
Clay (? Boulder)	2	0
Broken red shale....................	0	9
Red clay, with patches of brown sand	1	3
Grey shale	2	0
Red shale.........base not exposed		

The dip was about 5° a little north of east. At the end of section exposed, and at a point now marked by a manhole in the sewer, about 50 yards from Shrewsbury Road, these beds are seen to be thrown down against a soft yellow sandstone by a fault running north and south. About 12 yards from the fault the dip of the strata was reversed, as if bent upwards, and a second bed of grey shale exposed below the red shale. A few feet from the fault the beds were confused and broken, and a mass of yellow clay interposed between them and the face of the fault. The upper bed of grey shale appeared to lie between two similar beds of red shale, but on examination the upper one was seen to be much broken up, disturbed, and mixed with clay and sand.

The red and grey shales have been exposed on the opposite side of Wellington Road, a few yards farther south and opposite Oxton Nursery, but I have not been able to find how far they extend in that direction. The yellow sandstone has been exposed in several places on the east side of Talbot Road, 300 or 400 yards S. and S.W. of Well Lane and in a new street from Bidston Road to Wellington Road at a rather less distance to the west.

To Mr. Bostock I am indebted for the following localities to the N. and N.W. of Well Lane where he has

observed the Keuper marls exposed, viz.: Beresford Road, the Proprietary School in Shrewsbury Road, and in a road on Oxton Heath (Holbeck Road, running from St. Aidan's College to Bidston Road). In making this road, Mr. Bostock says, "they passed through a large fault, Keuper Sandstone on one side and Red Marl on the other; the sewer was sunk to a depth of from 8 to 12 feet, all in Red Marl." This fault is now visible in Lingdale Lane, a few yards from Holbeck Road.* It is not, however, clear whether the Red Marl extends continuously from Well Lane to this point, or whether we have a series of isolated patches.

Mr. Bostock continues: "Some few years since I "met with some Red Marl on the other (west) side of "Oxton Hill. . . . . just on the crest of the hill "where it overlooks the valley. The strange thing about "it was this: it was not *in sitû*, but had been brought "there." "It rested on the Keuper Sandstone, was "several feet thick, and consisted chiefly of thin flakes of "marl, not horizontal, as one would expect if they had "been brought by water, but at every angle vertical, even, "and with Boulder-clay over it undisturbed. However "this can be accounted for, there can be no doubt that it "implies great changes in the neighbourhood."

This bed seems to answer to the upper layer of red shale, also broken and disturbed at Well Lane; and I think it worth enquiry whether in both cases it may not have been broken up *in sitû*, as there is evidence in the neighbourhood of the upper beds of the yellow rock, where at all thin bedded, having been similarly disturbed; but this opens up another question, as to which it is not advisable to enter in this paper.

* Since reading this paper I have seen red and grey marls exposed on the west side of Bidston Road, a few yards north of Holbeck Road.

NOTES ON A BED OF FRESH-WATER SHELLS AND A CHIPPED FLINT LATELY FOUND AT THE ALT MOUTH.

By T. Mellard Reade, F.G.S., &c.

From time to time I have exhibited before this Society remains of mammalia found in the submarine forest at the Alt Mouth. They have consisted of bones of the horse, red deer, and *Bos longifrons*. Some of these bones have evidently been worked by human hands, mostly into a forked form, as if for lapping lines upon. The object of these articles and the uses to which they were applied are, however, not very clear at present. That they have been wrought or chipped is, however, patent, though it has been done in a rough way, as if with a flint implement, flakes having been gouged off in one case in a very marked manner. One bone shewed a splinter, evidently struck off with a very sharp point—it might be by an arrow. The worked bones are mostly, if not in all cases, those of the horse, which seem to have been the most abundant.

Most of the animal remains were found in a narrow belt crossing the shore. From the materials in which they were embedded—mixed blue clay, peat, and mud—and the general appearance of the ground, I inferred that they had been washed down by a stream which had ormerly carried the land drainage of Great Crosby and part of Little Crosby in this direction. It is situated near to the present outlet-drainage of these districts. The bed of peat (Superior-peat and Forest Bed) had been worn away by the stream, and the peat and mud had become mixed in its bed.

Just lately my sons have discovered a bed of fresh-water shells, which, on examination, I saw was in the same stream-bed, but at a higher level. It has been uncovered by the sea washing away the sandhills and baring the upper part of the shore of sand.

The shells, consisting of *Lymneus Lymnea, L. periger Cyclas cornea*, and *Planorbis spirorbis*, were crowded in a bed of mixed peat, sand, and mud, immediately under the sandhills, and about 6 inches thick—evidently occupying the site of the ancient stream-course.

Close to this bed a small flint flake was found, apparently blackened by lying in the peaty matter. It is evidently worked by human hands, and is rather hacked at the edges; it is of the common leaf form.

I exhibit another flint flake, much weathered, and white on the surface. Mr. F. Archer, who is an authority in these matters, considers it is undoubtedly of human workmanship. It shews the bulb of percussion very well, and the edges have been carefully trimmed. I could not, however, connect it with any bed, and therefore have not brought it to the notice of the Society until now. I have been for a long time past looking for worked flints in this district. I have often found flints, but until now could never learn anything from them.

A copper needle, supposed to be Roman, was found near the same locality, together with some small bits of old pottery. A bronze key was also found on the surface of the peat, about half a mile north of this stream. I have these relics in my possession.

The remains are very interesting, and perhaps in course of time something further may be discovered to throw light upon them. We find from these little discoveries that it is only when articles get into places where they become rapidly covered up that they are preserved for the information of future ages.

Since the above was written, my sons have dug a trench across the deposit. They took out of the fresh-water bed the upper part of the right *tibia* of a horse. The shaft has been either cut or gnawed—which, it is not quite plain. It was embedded 4 inches deep. Below the fresh-water bed, about 18 inches from the surface, they dug out the right scapula of a horse. These bones are of the usual small type, and the muscular characteristics they display would point towards the animals having been wild.

I exhibit also the left *tibia* of a horse, found on the surface near the same spot, in the line of the old stream-bed; also part of the *tibia* of a red deer, found on the shore. I am indebted to Mr. T. J. Moore for the determinations of the bones.

NOTE ON THE OCCURRENCE OF COPPER IN THE KEUPER SANDSTONE AT THE PECKFORTON HILLS, CHESHIRE.

By Osmund W. Jeffs.

The Triassic rocks around Liverpool have not yielded to the collector many varieties of minerals. A list of those occurring in the neighbourhood was compiled by our President, Mr. G. H. Morton, F.G.S. (*vide* "Proceedings" of this Society, vol ii., Session 1871, p. 91), but the mineral Copper is not included amongst those found in the Trias. The occurrence of Malachite in Coal measures at Thatto Heath is, however, noted, but I am not in possession of any details as to the condition in which the mineral was found there.

The only localities in Cheshire where Copper has been found in sufficient quantity to be worth mining are

at Alderley Edge, near Macclesfield, and at Gallantry Bank, in the Peckforton Hills.

The Peckforton range forms an elevated ridge extending from N.E. to S.W. for a distance of about 7 miles. The geological structure of the region is simple. The hills rise in a series of terraced escarpments formed of hard Keuper Basement Beds resting upon the softer strata of the Upper Bunter. To the N. and E. the district is bounded by faults, and several minor faults intersect the hills in varying directions.

Along the eastern foot of the ridge a fault throws down the Red Marl not less than 600 feet.* The fault is marked on the Survey Map as extending from Dean Bank Road (near the Toll Gate to the S.E. of Beeston Station) in an almost unbroken line to a point about 3 miles south of Malpas. The fault is not visible between Beeston and Bickerton, being hidden by accumulations of drift deposits; its course is however marked by a series of springs (Hull), some of which are to be observed along the wayside in the road leading from Bickerton to Peckforton.

The lode of Copper is found in the vicinity of this fault, and has been worked near Bickerton, at Gallantry Bank (about 4 miles from Broxton Station, on the Chester and Whitchurch line).

It may be convenient here to insert references to the localities where Copper has been found in the Keuper Rocks in Cheshire and Shropshire:—

1.—The earliest reference to the lode at Gallantry Bank is given in a memoir by Dr. HOLLAND, on the "Cheshire Rock Salt District," in the "Geological Transactions," vol. i., p. 39 (1811).

* *Vide* "Geol. Survey Memoir of Chester," by Aubrey Strahan, 1882, p. 14.

2.—W. PHILLIPS in his "Mineralogy" (3rd ed., 1823, p. 10), states that "blue carbonate of Copper occurs at Alderley Edge, in Cheshire, in sandstone with yellow Copper and barytes," but does not mention Peckforton.

3.—MURCHISON in his "Silurian System" (1839), gives several instances of the occurrence of this mineral in the Keuper of Cheshire and Shropshire:—

I.—"Section, near Marchamley, Hawkstone Hills, Salop.—Bed No. 3. —Hard red sandstone, calcareous. To the W. they change to a yellowish grey colour, including veins of chalcedony (with nests of crystallized carbonate of lime), blue carbonate of Copper and black oxide of manganese, disseminated both in particles and in small veins."

II.—Hawkstone Hills.—"The surface of the sandstone near the Hermitage is occasionally of a bright green colour, which is sometimes due to green carbonate of copper disseminated through the rock." [Murchison adds a warning note to the effect that "some of the specimens owe their green colour to the presence of a lichen."]

III.—Peckforton Hills.—"Examined the trial shafts of the old mine in company with the proprietor, Sir Philip Egerton, and there the ore unquestionably lies in veins and lumps where the sandstone is dislocated and fissured."

IV.—Near Pradoe (West Felton, Salop).—"Specimens of the rock sent to me by Col. Wingfield, indicate the dissemination of the green carbonate in minute quantities through the mass of sandstone."

4.—PROF. E. HULL, in his "Geological Memoir of the Trias" (1869), gives an illustration (p. 74) of a lode in the Waterstones at West Felton, Salop, where the sides of the fault contained a considerable quantity of green carbonate of Copper and some of the oxides of iron and manganese.*

* This is probably the same lode as the one mentioned by Murchison as existing "near Pradoe."

Of the Peckforton Hills, Hull states (p. 76) :—"The boundary fault is metalliferous, producing principally green and blue carbonate of Copper, and the oxides of manganese and iron. The veinstone, or slickenside, consists of white quartzose rock, with occasionally calcspar, which has probably been infiltered into the fissure from the sides, along with the metallic substances."

The lode at Gallantry Bank has been worked along the side of the hill in three shafts. The most southerly station comprised, in addition to the shaft, a pump and engine-house, together with some other buildings, which, however, when I visited them in 1883 were in a ruined condition, the mouth of the shaft itself being hidden by brambles.

The heaps of *débris* comprised blocks of sandstone, many pieces coloured slightly green, pieces of red and bluish marl, with pseudomorphs of rock salt crystals, and dendritic markings of oxide of manganese.

About a hundred yards from the first shaft is a second opening where the mineral vein is seen close to the surface; and, still further to the north, in an enclosure, the third shaft, about 15 yards deep, has been sunk. Specimens of the rock containing ore from each shaft are placed before you. On examination the rock is seen to be of a hard siliceous character, the grains of silica being mostly coated with carbonate of Copper. It weathers on the surface to a dark green colour. The dark spots seen in the interior of some of the specimens are hydrated oxide of Copper. In some of the specimens from No. 2 shaft the rock retains its white colour, slightly tinged with green, with a dark green layer running through the sandstone.

Mr. Charles Clifton Moore (of Northwich) has kindly

tested my specimens for Copper, with the result given below:—

ANALYSIS OF COPPER FROM THE PECKFORTON HILLS, CHESHIRE.

	Specimen No. 1.	Specimen No. 2.	Specimen No. 3.
A.—COPPER	8.56°/o	1.90°/o	7.86°/o

	Specimen No. 1.	Specimen No. 2.
B.—Silica	81.96	93.25
Carbonate of Copper.........	8.01	1.74
Hydrated Oxide of Copper	6.81	1.53
Carbonate of Lime	1.04	1.42
Magnesia	trace	trace
Ferric Oxide and Alumina	1.35	1.16
Water	.30	.54

The figures given for the carbonate of Copper and hydrate of Copper oxide, closely agree with those required by the theoretical composition of Malachite.

The occurrence of this mineral opens an interesting question of its origin. It may have been derived from the denudation of older rocks containing Copper, and deposited with the Triassic sandstone in which we find it; but its presence in the vicinity of faulted and broken rock would, I think, rather indicate its deposition from heated water which had obtained access within the fissure.

In addition to the localities mentioned above where Copper has been found in the Trias, I have had specimens of sandstone with traces of Copper pointed out to me by Mr. Charles E. Miles, in a small quarry at the foot of Beeston Crag. The Keuper rock here is much broken, and full of veins of sulphate of Barium, as also stated by Mr. Aubrey Strahan. This exposure

is situated in the vicinity of the northern extension of the same great fault which contains the lode at Bickerton, and it is possible that, if borings were made along the course of the fault towards Beeston, Copper would be found to occur in it, though probably not in great quantity.*

In the romantic rocks in Hawkstone Park, in Shropshire, I have observed patches of green carbonate of Copper in the white Keuper sandstone, at the entrance to the "grotto," an artificial excavation situated close to the high bridge over the rocky pass through which runs the park road to the Hall.

I revisited the old mine at Gallantry Bank, in August, 1885, and found it still in the same condition as previously described. I conclude, therefore, that up to the present time the quantity of Copper in the Keuper beds has not been ascertained to be sufficient to repay the trouble of working and extracting the ore, or to provide for the successful inauguration of a new Cheshire mining industry.

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* Since the above was written, Mr. A. Norman Tate, F.I.C., informs me that, a few years ago, in an analysis of water from a well on a farm at Spurstow, near Beeston, he discovered distinct traces of Copper. The farm is situated on the Red Marl, within two miles of the Peckforton fault, mentioned above.

NOTES ON THE TOPOGRAPHY OF LIVERPOOL.*

By W. Hewitt, B.Sc.

The first settlement forming the nucleus of the modern city of Liverpool appears to have been near the extremity of a small low ridge, in the form of a narrow peninsula, washed at its base on the western side by the waters of the estuary, and on the eastern side by the waters of a tidal creek, known as the Pool. This creek, which extended inland some three-quarters of a mile, formed a sheltered haven for the small vessels of the fishermen, who probably constituted the first settlers. On the brow of the ridge (now occupied by St. George's Church), a castle was built, which served to protect both the Pool and its approach. For a long time the town was confined to this small ridge, extending down to the water's edge on either side, and creeping slowly northwards along the summit; but gradually it overstepped the Pool and began to ascend the slopes of the loftier neighbouring hills.

The modern city occupies the whole of the western and a considerable part of the eastern slope of a sandstone ridge, running approximately north and south, having a somewhat steep slope on its western side, but a more gentle one towards the east. The western slope is steepest in the northern portion of the district, and is interrupted by a longitudinal valley, which was formerly occupied by a stream carrying the waters draining from this slope into the head of the Pool. In the southern portion the slope is broken by a large flat table-

* These Notes, compiled from various sources, were written in illustration of a topographical relief model of the district, constructed by the author, and exhibited before the Society,

land (about one and a quarter miles long by three-quarters of a mile broad), which was formerly in great part occupied by the Moss Lake. The eastern slope falls away from the summit of the ridge, northwards towards the Tue-brook and southwards towards the valley of the stream running into the Mersey at Otterspool. The culminating point of the ridge is St. George's Hill in Everton, where formerly stood the Beacon Tower, and where now stands St. George's Church; the height of this point, according to the Ordnance Map, is 247 feet. A second, though lower culmination is at Edge Hill, where, just to the north of St. Mary's Church, a height of 227 feet is reached. A third and more isolated summit forms the Park Hill; the site of the reservoir in High Park Street being given as at a height of 186 feet.

The uppermost part of this ridge is composed of the hard Pebble-beds of the Bunter formation, succeeded at a lower level on both slopes by the softer Upper Mottled Sandstone. The rock is overlaid in most parts by a moderately thick coating of Boulder-clay, which is again frequently covered by beds of sand, often discoloured by, and mixed with, peaty matter.

The district appears to have been partly covered by forest (as in the case of that portion of it included in the royal park of Toxteth), but the greater part appears rather to have been bleak and barren, and in its higher portions, according to Picton, "doubtless resembled the sister ridge of Bidston Hill, on the opposite side of the Mersey—an irregular common, covered with furze bushes, heath, and scanty pasturage." The district to the south of London Road and Shaw's Brow was long known as the Great Heath, and this, up to the beginning of the last century, was an unoccupied waste, traversed only by a few foot-roads.

The old *Moss Lake*, described by Picton as "an amphibious sort of district—water or marsh according to the seasons," occupied a considerable part (about 280 acres) of the level area already mentioned on the western slope of the ridge, at an elevation of about 160 feet above the sea. The district doubtless owed its swampy character to the clayey subsoil, and to the obstructed drainage resulting from its horizontal conformation. The area has so little fall in either direction that the mere clearing out or filling up of a ditch at its northern end could determine the drainage either across London Road to the head of the Pool or towards Toxteth Park. This circumstance gave rise to repeated disputes between the families of Sir E. Moore and Lord Molyneux. The latter, having water-mills in Toxteth Park, was therefore opposed to the clearing out of the ditch, which would carry off the waters northwards; whereas the obstruction of the ditch and the damming up of the water caused it to overflow Moore's turf grounds in the neighbourhood of the Moss Lake, and at the same time worked Lord Molyneux's mills in opposition to those of Moore. In the "Moore Rental," a curious document, bearing date 1667–8, Moore advises his son of the valuable store of fuel in this Turbary, saying, "Of my knowledge you have good black turf, at least 4 yards deep . . . . and if you leave half a yard ungotten, once in 40 years it swells and grows again." This district probably comprised the six acres (equal to twelve or thirteen statute acres) of mosses granted in 1309 by Thomas Plantagenet, Earl of Lancaster, to the burgesses of Liverpool, in consideration of the yearly payment of one silver penny. The district, being drained, was converted into common pasture land, and is now covered by Abercromby and Falkner Squares with the adjoining streets.

The line of the old *Shore* was considerably more inland than the present sea wall—in some parts more than one-third of a mile—inasmuch as in the construction of the vast system of docks much of the foreshore has been reclaimed. The old shore line is pretty well indicated by the line of Regent Road, Waterloo Road, Back Goree, Strand Street, and Wapping. The shore was for the most part sandy, and fringed in its northern portion with low sand hills; in one or two places there would seem to have been low rocky projections. According to the "Moore Rental," the waste of the shore was at that time very great, for Sir E. Moore advises his son, with regard to Sea Bank (near the bottom of Chapel Street): "If you do not prevent getting stone or cause a wall to be made, you will have all the croft belonging to Tho. Landell washed clear away; and I pray God the Parlour Hey will not be washed away, for much of the bank over against it of my knowledge is;" and again he states that whilst his grandfather made a lease of the bank for thirty shillings a year, "now it is so much worn away with the sea that I cannot make five shillings a year of it."

The old *Pool*, or creek, is said to have been about 1,200 feet wide at its junction with the estuary, close to the site of the present Custom House. It followed the line of Paradise Street (formerly called the Common Shore) and Whitechapel, narrowing rapidly to 200 feet at the foot of Lord Street, where it was crossed by a stone bridge. It continued as a narrow inlet along the west side of Byrom Street to the bottom of Richmond Row, where it received the waters of two streams, one from the north, and the other from Moss Lake by way of Daulby Street and St. Anne Street. The tide seems to have been felt at least as far as the bottom of Dale

Street, where the old Townsend bridge was. The course of the Pool was somewhat variable, probably owing to the deposition of silt, for in the town's records (quoted in Sir J. Picton's "Municipal Archives") we read: "Item, that the water course shall be cleansed that runneth under the bridge at the Town's End, for that it is gone from the right course." The Pool was navigable only at high water, and for a long time the project of cutting and deepening it to form a harbour was under discussion, but with no practical result. In 1709 the Corporation obtained an Act of Parliament, enabling them to construct a dock (about 4 acres in extent) in the bed of the Pool, close to the estuary. This, which was known as the Old Dock, was constructed, and remained till 1826, when it was filled up, and its site is now occupied by the Custom House, &c. After the cutting off of the tidal waters by the construction of the dock, the course of the Pool, which for some time was represented by a swampy ditch on the east side of Whitechapel (then called Frog Lane), was reclaimed, to the extent, it is said, altogether of about 50 acres.

Numerous *streams* of small size took their rise on the slopes of the ridge, and made their way for the most part into the estuary of the Mersey. In several cases these water-courses have been adopted at one period or other as natural boundaries of certain divisions of the district. The most important streams in the district represented by the model were as follows:—

(1.) A small brook, marked on old maps as the "Bank Hall Brook," took its rise just to the west of Westminster Road, running round the south face of the site of Kirkdale Gaol, forming a small dingle or dell, and running into the river just to the north of what is now the Huskisson Dock.

(2.) A stream made its way southwards at the foot of the main ridge, near Walton Road, and almost along the line of Great Homer Street, through the site of the New Haymarket, and across Nash Grove, falling into the head of the Pool at the bottom of Richmond Row.

(3.) From the Moss Lake a water-course ran northwards along the line of Crown Street, across Daulby Street to the corner of Stafford Street and London Road, where a reservoir was at one time constructed; then along St. Anne Street to Circus Street, where it formed another dam, just before falling into the Pool at the same place as the one last described. This water-course was, according to Sir E. Moore, the natural outlet for the waters of Moss Lake, but it appears at times to have been allowed to become more or less filled up.

(3a). Another stream, taking its rise near the Necropolis, ran down the slope just to the north of Brunswick Road (forming the boundary between West Derby and Everton), and joined the stream from the Moss Lake at Daulby Street.

(4.) The lake in Prince's Park lies in the course of a stream, which took its rise in the Parliament Fields. The valley can be distinctly traced from Devonshire Road through the park, across Aigburth Road, to join the Mersey near St. Michael's Hamlet, its valley being known as Dickenson's Dingle.

(5.) The Dingle brook rose somewhere near the summit of the Park Hill, and ran near the line of Park Road, joining the Mersey through a pretty dingle just behind the rocky promontory in that neighbourhood.

(6.) Another brook, rising probably not far from the junction of Grove Street and Parliament Street, and which doubtless was the stream which sometimes served to carry the surplus waters of the Moss Lake

southwards, ran along the line of Warwick Street, through the depression crossing Windsor Street, to the Old Mill, which stood at the south corner of Upper Warwick Street and Park Road. Here it formed a dam, and then made its way down to the river near the south end of the Queen's Dock.

(7.) A stream rising somewhere in the neighbourhood of Sheil Park, and passing through Newsham Park, carried the waters from the north-eastern slope into the Tue Brook, which runs into the Alt.

(8.) The southern portion of the eastern slope drained towards the valley which runs across Smithdown Road opposite the cemetery. In this valley ran a small stream, which took its rise in the higher ground about Edge Lane, and which now in part of its course forms a portion of the municipal boundary. The course of this brook can be traced across Smithdown Road, through the cemetery and across Ullet Road into the head of the lake in Sefton Park. Near the middle of the Park it is joined by another stream, which ran nearly parallel, but more to the east, and on its course passed through the lake at Greenbank. The water of the united streams, under the name of the River Jordan, fell into the Mersey at Otterspool.

It may be interesting to add a few notes concerning the *Water Supply* of ancient Liverpool. For a long time a sufficient supply of water was obtained from natural springs issuing from the ground on the western slope of the sandstone ridge, as at Copperas Hill and Brownlow Hill, and also from shallow wells sunk in the sandstone. The old "Fall Well," situated on the Great Heath, about the corner of St. John's Lane and Roe Street, is spoken of as the common well of the town, and appears to have been originally a copious spring of good water,

carefully protected by a stone wall. The "Dye-house Well," the road to which (now called Argyle Street) is marked on some old maps, was situated on the site of Greetham Street, near Cleveland Square, and was said at one time to yield the best water in the district for culinary purposes. "Gregson's Well" was another public spring, situated at the corner of Brunswick Road and Everton Road. Sir E. Moore, in his "Rental," says that in a well sunk by himself in Moore Street he found water at 14 yards, whereas in several wells sunk in the Water Street a depth of 20 yards was necessary. He goes on to say that the water from most of the draw wells in the town was brackish or salt, and would not bear soap, so that "the whole town in general send to a place called the Fall Wall Well, a quarter of a mile upon off the town, for each drop of water they wash with or boil pease withal." He states, however, that the water from his well in Moore Street "boils pease and bears soap well." These sources of supply, however, were unable to meet the demand as the town increased, and schemes were started for bringing water on the one hand from Moss Lake, but more especially from copious springs at Bootle, some three miles distant. This last scheme was indeed carried out at the end of the last century; and at the same time a rival company, favoured by the Corporation, was established (known as the Liverpool and Harrington Company), to develop the resources of the local springs. In Billinge's "Liverpool Advertiser" for June 5th, 1797, it says—"The water from Copperas Hill may well supply the eastern part of Liverpool, whilst the water from Bootle may supply the northern district." From these sources the water supply of the town was obtained until the Rivington scheme came into operation.

A mineral chalybeate spring issues from the section of rock exposed on the east side of the old quarry which now forms St. James' Cemetery, near the Huskisson monument. It was formerly considered of some importance, and in 1773 Dr. T. Houlston published a pamphlet extolling the medicinal properties of this spring. He gives the following description:—"The waters of the Liverpool Spa springs or oozes through veins of that soft yellow stone in the quarry near St. James' Church, generally used here for building, which owes its colour to the iron which it contains. This stone hardens in the air, and when calcined is of a red colour. . . . The water trickles slowly into an irregular bason; it is naturally limpid, though frequently found otherwise owing to the ochre which it deposits on the escape of the fixed air." He claims that the water is peculiarly adapted to promote appetite and digestion, and to strengthen the tone of the stomach, and is useful in the first stage of consumption, &c.

The *Boulder-clay* has been largely used for brickmaking, extensive areas having been stripped down to the underlying sandstone for this purpose. Brickmaking is recorded as having been carried on on the Great Heath; there were also at different times brickfields between Byrom Street and Marybone, along the west side of Scotland Road and on both sides of Stanley Road, on both sides of West Derby Road, on the north side of Smithdown Road, and over large areas in Toxteth Park to the north of Parkhill Road, and between Park Road and Prince's Road.

The *boulders* contained in the clay have been extensively employed for the pavement of the streets; but fortunately this form of pavement, unsatisfactory both as to sanitation and comfort, has now given way in all the

important streets to one formed of regularly shaped setts imported from North Wales and other districts.

Quarries for building stone have been worked in almost all parts of Liverpool. Some of the most important ones appear to have been as follows:—The Bankhall Quarry between Stanley Road and Orrel Road; one still open near the corner of Everton Valley and St. Domingo Road, and another somewhat to the west of this. Of this latter, Syers, in his "History of Everton," says:—"It is remarked of the stone procured at this north quarry of Everton, that after exposure it suffers the elements very early to cover and encrust its exterior surface with a thin mossy coat, and it also abounds with small flinty pebbles, which are very frequently studded and embedded in the solid or freestone." Quarries were worked on both sides of Brownlow Hill, near the site of the Workhouse; at the top of Edge Hill, near the Church; near the old reservoir in Norton Street; and in Rathbone Street. In the south end quarries were worked on the east side of Park Road, near the end of Northumberland Street, and near the junction of Wellington Road and Park Road. But the largest and most important quarry was that which was afterwards converted into St. James' Cemetery; and the rubbish and débris from which was, during a period of distress in 1767, at the expense of the Corporation, orderly and regularly arranged to form what was originally called Mount Sion, but what is now known as St. James' Terrace or The Mount.

BOULDERS WEDGED IN THE FALLS OF THE CYNFAEL—FFESTINIOG.

By T. Mellard Reade, F.G.S.

Near to Ffestiniog to the south-west are the well-known and picturesque Falls of the Cynfael. They extend a distance of about three-quarters of a mile towards where the road to Trawsfynydd crosses the stream to Pont Newydd. The rock which the stream traverses, and has cut into such marvellously varied glens, pools, and falls, belongs to the Lingula beds of the Lower Silurian. Much of the variety, and tortuous nature of the channel, is due to the combination of the regular dip with irregular jointing of the beds by which the water has been led from joint to joint, eroding and widening them, leaving here a cliff, and there a deep, narrow channel, or now passing round on either side of a mass of uneroded rock, and so pursuing its way from fall to fall. Such a central pillar of uneroded rock is the well-known Hugh Lloyd's Pulpit, which it is easy to see owes its existence to the irregular joint planes which bound it, and from which the ever busy brook has been for ages removing the surrounding rock. Above Hugh Lloyd's Pulpit is a rustic bridge crossing the falls to a house called Cynfael.

Higher up again is a deep and solemn pool, with cliffs on one side (the right bank) rising, I should say, over 100 feet high.

At a point across a deep cut or channel in the rock, at the bottom of which the stream flows, the beds of the rock have slid over one another, forming a corbelling over the stream (Fig. No. 1). By an additional slab

placed at *a*, Fig. 1, on the nose of the corbel, and at *b*, on the opposite side of the channel, this has been artificially converted into a good crossing. The question naturally occurs, why do not these large slabs of rock go on sliding, and tumble into the stream? At another point in the stream the question is answered, for there is an immense slab of rock (like a landing) on edge in the stream itself. It shows us that the processes of nature go on very slowly. Probably the freezing of water in the joints is the moving cause, so that as the joints widen the speed of separation or movement may possibly decrease. The dip of the rock is about 10° N. by E., and there do not appear to be any clay partings to lubricate the beds and make them slide. Unless there were great friction between them the slabs could not possibly remain in their present position.

Further up beyond the pool the stream-way gets very narrow and tortuous, and here were several very large boulders stuck fast and wedged in between the natural walls of the channel, and suspended over the stream, which was then running, I judged by eye, about 6 feet below the under surface of the boulders (see Fig. 3). The down-stream boulder (D Fig. 2) is of felstone, probably from Manod Mawr, and is well polished and rounded on the up stream side, which is convex. The down-stream side is slightly concave, but less polished on the surface. The concavity seems a rude continuation of that of the adjoining rock or wall of the channel against which the boulder is wedged. Another and larger boulder (E Fig. 2), of more irregular form, is also wedged in the stream on the up-stream side of the first boulder described. It appears to be of volcanic ash, and I should judge it to be 12 feet on the longer axis. At the side of, and between these boulders, on the left bank (C on Fig. 2) the swirl

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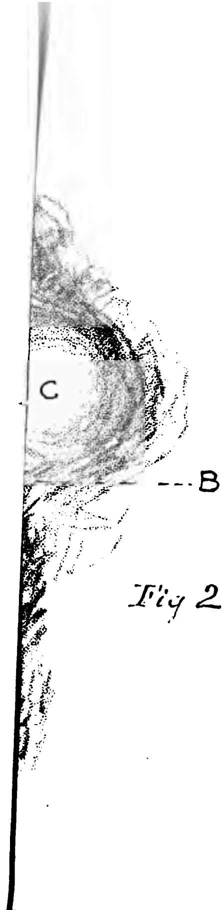

Fig 2

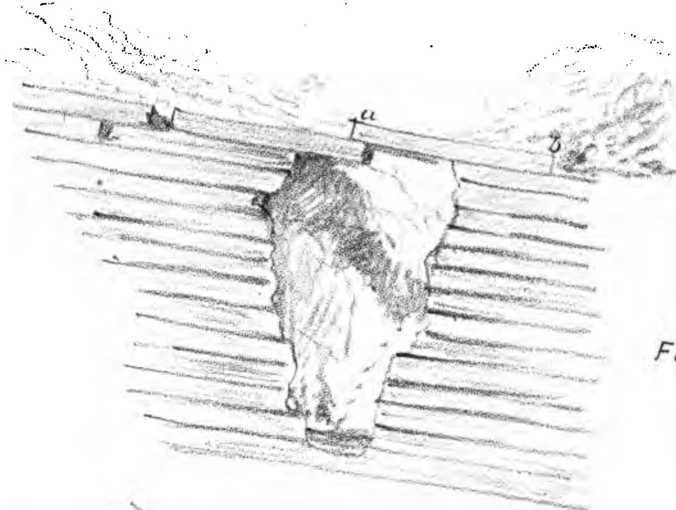

Fig 1

Fig 3

A to B

of the stream has excavated a caldron in the rock as perfect as the inside of a washing copper, and immediately below the first boulder described is another, but not so perfect.

After recognising the relation of these boulders, the stream, and the rock, we cannot avoid asking ourselves how they came to be fixed in this curious position? Tracing the stream above, we ascertain with certainty that they could not possibly travel down the existing narrow and irregular channel. On the other hand, it does not seem probable that they have fallen from above, for from their being in juxtaposition it looks more like as if they had travelled down, and both become jammed at the same point.

If this be so, and of it I have little doubt, the boulder must have travelled down stream probably with the assistance of ice, when the stream was of a less depth and wider at the bottom. It is not improbable they may have been left at some point in the stream during the Glacial Period. The *distance* they have travelled in the stream itself it is of course impossible to tell, and is really not of much moment. What is of importance to note is the extreme probability that the boulders have been polished by the flowing water when the stream bed was higher—it must seldom if ever reach them now—and that the whole of the narrow and deep channel under them has been scooped out since they became jammed in their present position. The adjoining caldrons have been worn out by the diversion and swirl of the stream caused by the constricting boulders. I observed no similar holes elsewhere in the stream bed.

This appeared to me a new and exceedingly interesting problem. Unfortunately we have no known measure of time applicable to the erosion of a stream bed. Perhaps this may some time disclose itself.

A SECTION OF THE TRIAS AT VYRNWY STREET, EVERTON, DISPLAYING EVIDENCE OF LATERAL PRESSURE.

By T. Mellard Reade, F.G.S.

The excavations for the basement of the new Board Schools in Venice Street, Everton, disclosed some peculiar contortions in the rock not far below the surface, apparently shading off into a thin superficial covering of drift immediately above. As I should like members who have the opportunity to look out for similar phenomena, I bring the matter before the Society to excite their attention and aid in explaining it.

The excavation was nearly all in the Pebble Beds of the Trias, and Fig. 1 is a plan of it.

The side of the excavation at A B, adjoining Vyrnwy Street shewed the contortions represented in the Section A B, Fig. 2.

A bed of micaceous clay of variable thickness, but nowhere exceeding 9 inches, was interbedded in the rock C to B on plan. At D, on Section A B, it appeared to be squeezed up vertically against a face of hard rock, a more shaly rock overlying it. Above, the rock shaded off into a sandy drift, E E. The micaceous clay band threw out tongues into this (F F'), and appeared much and confusedly kneaded up. Further in the band was overlain by shaly loose rock, and it died out at about A on plan.

I find it very difficult to explain these curiously mixed contortions in a satisfactory manner. They seem partly due to rock movement at a very early period, probably long previous to the land denudation the Triassic beds have undergone; for it is difficult to conceive how the

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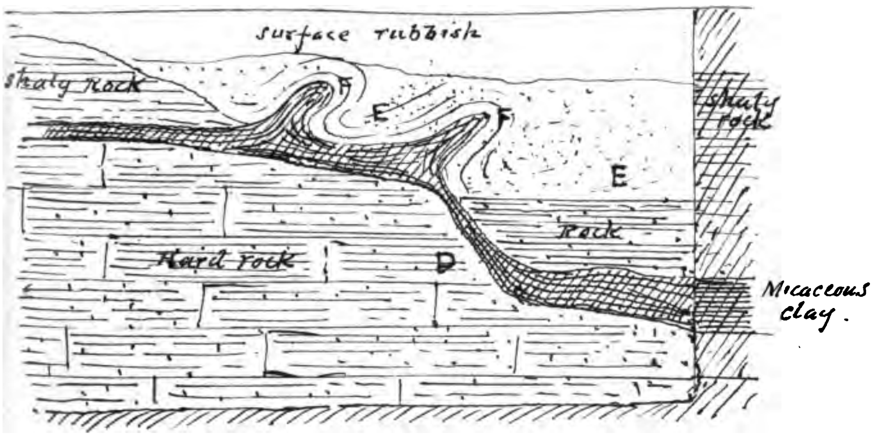
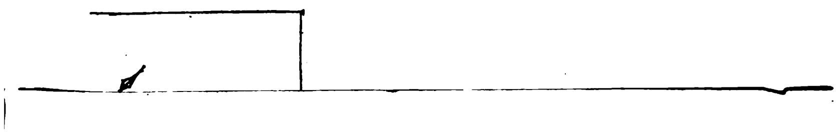


Fig. 2 SECTION A. B

VENICE STREET



long previous to the land denudation the Triassic beds have undergone; for it is difficult to conceive how the

micaceous clayey band could have been deposited vertically, as at D E. It also bore the appearance of being squeezed thin at this point. At the same time the tongues F F projecting into the drift sand seemed an after modification.

That the Triassic beds, at a early period, have been subject to lateral movements I am satisfied, from the numerous horizontal slickensides met with. The apparently superimposed contortions of the micaceous clay band occurring in the drift period are very irregular.

At the North-west corner was a small vertical fault (F F in plan, Fig 1); striking a little West of true North, it was to be seen at both sides of the excavation (G and H). At H the shaly rock very perceptibly curved upwards to the fault on either side.

As the lateral pressure the Trias has been subjected to acted, according to my observations, generally in a West to East direction, the curvature of the fissile beds may be due to the same cause, or it may be simply the effect of the faulting.

These suggested explanations may be proved or disproved by further observations. I feel pretty sure in any case that many more examples of lateral pressure will be found in the Triassic rocks than have been recorded, if they are diligently looked for. In fact it seems remarkable to me that so little notice has been taken of the horizontal slickenside phenomena which point to the same origin.

ON THE ORIGIN OF PETROLEUM AND OTHER NATURAL HYDROCARBONS.

By A. Norman Tate, F.I.C.

The most generally accepted theory of the origin of petroleum supposes that it has been derived, by a process of natural distillation, from previously existing matters, such as coals, cannels, shales, pyroschists, lignites, &c. This theory no doubt originated from the fact that by treating these several substances by distillation in the laboratory or manufactory, hydrocarbon liquids, solids, and gases are obtained.

Other theories have from time to time been put forward, but have not met with much support, but I believe they are worth more attention than has been given them. The consideration of the subject is surrounded by many difficulties. Petroleum and other hydrocarbon deposits occur in strata of all ages and in all parts of the world, so that we have not the advantage of discussing their origin under circumstances of relation to any particular strata, or geological age, &c. So widely different are the circumstances surrounding their occurrence, that experience gained in obtaining them in one part of the world is of little use in another. For example, a knowledge of the geological formations in which petroleum occurs in the United States is of little use in seeking it in Russia or other countries where it exists. Then, again, as regards the liquid petroleums, their liquidity on the one hand and their volatility when subjected to heat on the other, make it probable that they have not in many cases remained in the actual place of origin. By reason of their liquidity they may have passed to lower levels, or have been volatilised to higher, so that the position

in which they now occur may not give much indication of the sources from which they were derived. On this however, I would point out that it might reasonably be supposed that traces of their presence would be found in the strata intervening between their source and the position in which they are now found. This point is, I think, often lost sight of in discussing the subject.

Natural hydrocarbons vary from liquids of light density, such as the petroleums of Pennsylvania, to solids such as the asphalts. They also vary much in the nature of the several constituents present in them or obtainable from them. The American petroleums, for example, yield far more of the lighter volatile products than do the Rangoon or Russian oils, both of which have a large proportion of the heavy liquids such as are used for lubricating oils, whilst what is known as Barbadoes tar and Trinidad pitch have in them scarcely any of the lighter volatile oils.

In chemical composition we find also well marked differences in the special series of hydrocarbons present in one petroleum as compared with another. The American petroleum consists chiefly of hydrocarbons of the formula $C_n H_{2n+2}$ and contains paraffin. The Rangoon oil is similar, but contains more paraffin and more of the heavier members of this series; whilst the Russian oil contains hydrocarbons of the $C_n H_{2n}$ series, a considerable proportion of benzenes and other benzenoid hydrocarbons.

All these variations in character and composition point to difference either of source or mode of origin. To suppose a process of distillation of bituminous minerals or other hydrocarbon-yielding substances seems to me unnecessary. I am more disposed to believe that petroleum has been produced by somewhat similar

processes of decomposition of vegetable matters to those which we suppose have occurred during the formation of peat, lignites, coals, cannels, &c. In other words instead of considering petroleum as the result of the distillation of previously existing substances of the character just named, I believe it may have resulted from the action of chemical changes of similar character to those which produced these substances themselves.

When wood, the composition of which may for the present purpose be set down as $C_{12}\ H_{20}\ O_{10}$ (the composition of cellulose), is subjected to the action of air and moisture, oxygen is absorbed from the air, and carbonic acid (CO_2) and water (H_2O) are evolved in the proportion of one equivalent of carbonic acid to two of water; so that there would result during the process of decay by the absorption of oxygen and the elimination of carbonic acid and water, a series of substances gradually becoming richer in carbon in proportion to hydrogen and oxygen, and finally a residue of carbon only would be left.

But where woody fibre is so placed as to be excluded from the oxygen of the air, other reactions are conceivable. The whole of the oxygen may be given off as CO_2, whilst the hydrogen remains with the residual carbon, or instead of combining exclusively with the carbon, a portion of the oxygen may combine with hydrogen and be set free as water; and it is quite possible to show that the elements of the wood may by evolution of carbonic acid and water in various proportions, yield substances having either the composition of coals, or bitumens, or ordinary petroleums.

It is impossible to say what are the precise conditions which favour the production of petroleum rather than coal; but we are acquainted with certain transformations

of organic substances which show that under different conditions the same body may produce very different products.

Professor Sterry Hunt, who has written much on the origin of petroleum, gives a table which shows the relation of different coals, petroleums, peats &c., to woody-fibre, and this I give below, with some few additions and alteration of formulæ to suit modern chemical notation. The formulæ placed opposite the several substances must be taken to show their *relative* composition as compared with cellulose, rather than their *actual* constitution.

Cellulose (vegetable fibre)		$C_{12}\ H_{20}\ O_{10}$
Cork		$C_{12}\ H_{18}\ O_{8}$
Lycopodium		$C_{12}\ H_{19}\ NO_{8}$
Peat		$C_{12}\ H_{14}\ O_{5}$
Brown Coal		$C_{12}\ H_{14}\ O_{5}$
Lignite		$C_{12}\ H_{11}\ O_{8}$
Bituminous Coal		$C_{12}\ H_{10}\ O_{1\cdot5}$
Do.		$C_{12}\ H_{10}\ O_{1}$
Do.		$C_{12}\ H_{8}\ O_{0\cdot5}$
Albert Coal		$C_{12}\ H_{16}\ O_{1}$
Coal passing into mineral resin		$C_{12}\ H_{15}\ O_{1\cdot5}$
Asphalt		$C_{12}\ H_{14}\ O_{1}$
Bitumen of	Derbyshire	$C_{12}\ H_{22}\ O_{0\cdot1}$
Do.	Bastennes	$C_{12}\ H_{16}\ O_{1}$
Do.	Naples	$C_{11}\ H_{14\cdot6}\ O_{1}$
Do.	Mexico	$C_{12}\ H_{17}\ O_{1}$
Do.	Idria	$C_{12}\ H_{8}$
Petroleum (American)		$C_{12}\ H_{24}$

These figures show clearly how, by the elimination of carbonic acid and water, cellulose may develop bituminous minerals and petroleum.

We know that in marshy districts, and other places where vegetable decomposition is going on, gaseous

hydrocarbons are given off in notable quantity, as in the production of marsh-gas, a member of the $C_n\ H_{2n+2}$ series, which gives rise to "Will-o'-the-wisp;" and if one member of the series can be produced by ordinary decay, why not others?

Many formulæ might be given to show how such arrangements of elements might occur as would produce hydrocarbons such as are present in liquid petroleums and other bitumens. For example, supposing that during the decay of woody fibre all the oxygen was given off as carbonic acid, there would remain $C_7\ H_{20}$, which would probably at once break up into marsh gas and a body containing less hydrogen, and supposing two molecules of marsh gas to be produced, there would then result a body having the composition $C_5\ H_{12}$, which is the composition of one hydrocarbon that largely exists in American petroleum; whilst in reference to the production of marsh-gas, it must be remembered that hydrocarbon gases largely occur in connection with petroleum.

The following formula shows the change:—

$$\underset{\text{Cellulose.}}{C_{12}\ H_{20}\ O_{10}} = \underset{\text{Pentane.}}{C_5\ H_{12}} + \underset{\text{Marsh Gas.}}{2CH_4}$$

Or if instead of combining exclusively with the carbon, a portion of the oxygen of the wood combined with parts of the hydrogen and was set free as water, and another portion united with carbon to form carbonic acid, there might be produced a body such as the bitumen of India

$$C_{12}\ H_{20}\ O_{10} = 2CO_2 + 6H_2O + C_{10}\ H_8$$

Although the supporters of the distillation theory point to certain anthracite and other non-bituminous deposits as the probable residues of distillation, it seems to me that there are wanting—First, evidence of such physical characters as would be produced by distillation; Second, evidence of traces of petroleum in strata intervening between source and occurrence.

Sterry Hunt,* referring to the position taken up by certain geologists, that the petroleum arises from the distillation of bituminous shales and pyroschists, and that its presence in certain oleiferous limestones—such as the Niagara limestones and Trenton and Corniferous formations—is due to infiltration, and arises from the distillation of bituminous shales and pyroschists, points out that the pyroschists contain no bitumen, and that, although their property of yielding hydrocarbon oils in common with other substances is undoubted, they rarely contain any; and that they do not present evidence of being distilled wherever taken, but retain their property of yielding hydrocarbons. Also that the process of distillation being presumably one of ascension in the case of the petroleum of the Silurian and Devonian limestones, it must have been derived from the Utica Slate beneath; but this rock is unaltered, and the intermediate sandstones and shales of the Loraine, Medina, and Clinton formations are destitute of petroleum, which must have passed through all these strata to condense in the Niagara and Corniferous limestones. He also points out that the Trenton limestone on Lake Huron, which has yielded much petroleum, has no pyroschists beneath it, but rests on crystalline rock, with the intervention of a sandstone which has no petroleum in it.

Very numerous other examples of a similar character might be given of want of evidence of passage from place of supposed origin to place of actual occurrence, and of absence of indications of distillation of the supposed residues, and these important items not being forthcoming, is in my opinion a grave difficulty in supporting the distillation theory.

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* "Geological and Chemical Essays," by Sterry Hunt. 2nd edition. Trubner & Co. 1879.

Of course distillation may be looked upon as varying much in character, and there may have occurred just that slow quiet action that would not produce in the residues appearances which we might under most circumstances of distillation expect to find; but it is difficult to suppose such distillation to have taken place without showing some connecting link in the form of bituminous matters or residues therefrom in the intervening strata.

Much may be urged also in support of ordinary decomposition as against the distillation theory in the occurrence of vegetable remains in many bituminous deposits, as for example in the pitch lake of Trinidad.

Although the foregoing remarks deal more especially with transformations that may have taken place in vegetable matters, we must not lose sight of the fact that it has been suggested that the source of petroleum is not altogether vegetable, but that it may have an animal origin. With reference to this it is interesting to consider the very extensive occurrence of petroleum in limestone rocks, &c., and the possibility of its production by decomposition of organisms that lived in the structures of which limestone rocks so largely consist. I need scarcely mention the wide occurrence of petroleum in limestone formations of North America and other countries, but I would also call attention to the occurrence of petroleum in limestone formations very close to our own neighbourhood. Few of the Welsh limestones are free from some traces of hydrocarbon. Some of the limestones of the Isle of Man are strongly impregnated with it. Without saying that the hydrocarbon matter in these deposits is really the result of the decomposition of animal remains, I would urge that the suggestion is worth far more consideration than seems to have been given to it.

I would also call attention to the theory of Mendelejeff (see "Revue Scientifique," November 3, 1877). He suggests the production of hydrocarbons by the action of water at high temperatures on compounds of carbon, iron, manganese, &c. We know that there can be produced a combustible gas (the so-called water-gas) by the action of steam on hot coke or other carbonaceous fuel, and that hydrogen may be obtained by passing water vapour over red hot iron or other metals; and these and other reactions give countenance to Mendelejeff's suggestion, and we can therefore consider the possibility of the production of hydrocarbon gases and liquids by the contact of water with carbonaceous matters, carbonates, and other compounds in the highly heated conditions in the interior of the earth.

In connection with this we may well note the occurrence of the large quantities of natural gas in many parts of the North American continent, quantities so large that in several places companies have actually been formed to utilise it for lighting and heating purposes.

With regard to the more solid bitumens and asphalts, they are probably derived from the evaporation of the lighter products of the more liquid petroleums, a process which can be readily imitated by evaporating any liquid petroleum to the condition of a tar, or pitch, or even coke.

In conclusion, whilst I by no means deny that distillation of bituminous minerals and other hydro-carbon-yielding substances in the interior of the earth, with production of petroleum, may in some cases have occurred, I urge that the process of slower decomposition is more probable. I would also ask for more attention to the ingenious theory of Mendelejeff of the action of water on highly heated matters.

ON FOOTPRINTS AND PLANTS IN THE TRIAS AT OXTON HEATH.

By Charles Ricketts, M.D., F.G.S.

In the making of a sewer, extending northward from Wicklow Road, Oxton, parallel with Bidston Road, many slabs of Keuper Sandstone were exposed, bearing upon them casts of the footprints of quadrupeds, and of the impressions of leaves of plants. The bird-like imprints of *Rhynchosaurus* were exceedingly plentiful, but none can with any certainty be recognized as consecutive. There are also examples of another animal, the marks of whose feet are in much greater relief (indicating greater weight) and the toes are not so long. No instance of *Cheirotherium* was met with.

The casts of two kinds of leaves have been found on these slabs; one of these leaves, which was found in considerable numbers, is long and narrow, about a third or a fourth of an inch across at the widest part, and very gradually tapers to a point. Some have a ridge or midrib extending down the middle of the leaf. The shape and appearance would indicate an alliance with sedge or grass. The other leaf is spear-shaped, 4 inches or more in length, and $1\frac{3}{4}$ or $2\frac{1}{2}$ inches wide, the broadest part being near the base, from which with a gentle curve it tapers to a point.

Respecting the footprints it is accepted by all that, in the first place, there has been a stratum of clay over which the animals walked; a layer of sand afterwards filled up all inequalities and hollows, and thus formed moulds o the feet of the animal in the impressions left in the mud. The same has occurred in respect to the plants, with this difference: the layer of sand has covered

up the leaves, &c., and it was not until they became decomposed and dissipated that the still loose sand filled up the space they had once occupied, and thus moulds of the plants themselves were formed.

No description of the section as exposed in the sewer can be given; it was not until the drain had been completed that the slabs were observed; but the attention of the Society should be especially directed to this locality, so that opportunities of obtaining more of these interesting relics are not missed. There is every prospect that within a short time further excavations for the foundations of houses and drainage will be made.

THE CARBONIFEROUS LIMESTONE AND CEFN-Y-FEDW SANDSTONE OF FLINTSHIRE.

By G. H. Morton, F.G.S.

(*Continued from Page 49, Vol. IV.*)

LIST OF FOSSILS FOUND IN THE MIDDLE WHITE LIMESTONE, NEAR MOLD.

1 *Aviculopecten*, sp. ....Llandegla.
2 *Euomphalus*, sp. ....Cefn-mawr.
3 *Athyris expansa*, Phil. ......Llanarmon.
4 *Productus cora*, D'Orb. ....Cefn-mawr, Cilcain, Berth-y-Chwarel, Hesp Allyn, and Llandegla.
5 ,, *giganteus*, Mart....Berth-y-Chwarel and Llanarmon.

6 *Productus Martini*, Sow. ...Llandegla.
7 „ *semireticulatus*, Mart...Cefn-mawr and Llandegla.
8 *Spirifera bisulcata*, Sow.......Caerwys and Llandegla.
9 „ *elliptica*, Phil. ......Berth-y-Chwarel.
10 „ *glabra*, Mart. ......Cefn-mawr and Berth-y-Chwarel.
11 *Alveolites septosa*, Flem.......Cefn-mawr and Bryn-gwyn.
12 *Clisiophyllum turbinatum*, M'Coy...Cefn-mawr and Berth-y-Chwarel.
13 *Cyathophyllum Stutchburyi*, M. Edw...Berth-y-Chwarel.
14 „ sp.......... „
15 *Lithostrotion irregulare*, M'Coy...Berth-y-Chwarel, Llandegla, and Cefn-mawr.
16 „ *junceum*, Flem...Llandegla.
17 „ *Portlocki*, M. Edw....Berth-y-Chwarel.
18 *Syringopora geniculata*, Phil....Cefn-mawr, Cilcain, and Llandegla.
19 *Zaphrentis*, sp. ....Berth-y-Chwarel.

The number of localities gives an indication of the frequency of each species, but *Productus cora* is much more common than any of the others.

LIST OF FOSSILS FOUND IN THE UPPER GREY LIMESTONE NEAR MOLD.

1 *Psephodus*, sp. (teeth of).
2 *Goniatites sphæricus*, Mart., or *crinistria*, Phil.
3 *Bellerophon tenuifascia*, Sow.
4 *Murchisonia Verneuiliana*, M'Coy.
5 *Aviculopecten micropterus*, M'Coy.
6 *Sanguinolites curtus*, M'Coy.

7 *Solemya Puzosiana*, Koninck.
8 *Athyris ambigua*, Sow.
9 *Orthis Mitchelini*, Lév.
10 „ *resupinata*, Mart.
11 *Chonetes Hardrensis*, Phil.
12 „ *papilionacea*, Koninck.
13 *Productus cora*, D'Orb.
14 „ *costatus*, Sow.
15 „ *fimbriatus*, Sow.
16 „ *giganteus*, Mart.
17 „ *latissimus*, Sow.
18 „ *longispinus*, Sow.
19 „ *Margaritaceus*, var. *pectinoides*, Phil.
20 „ *Martini*, Sow.
21 „ *punctatus*, Mart.
22 „ *semireticulatus*, Mart.
23 „ *Youngianus*, Dav.
24 *Spirifera crassa*, Koninck.
25 „ *bisulcata*, Sow.
26 *Fenestella plebeia*, M'Coy.
27 *Alveolites septosa*, Flem.
28 *Clisiophyllum turbinatum*, M'Coy.
29 *Cyathophyllum Stutchburyi*, M. Edw.
30 „ *regium*, Phil.
31 *Lithostrotion irregulare*, M'Coy.
32 „ *junceum*, Flem.
33 „ *Portlocki*, M. Edw.
34 *Lonsdaleia duplicata*, Mart.
35 „ *rugosa*, M'Coy.
36 *Phillipsastrea radiata*, M. Edw.
37 *Syringopora geniculata*, Phil.
38 „ *reticulata*, Goldf.
39 *Calamites*, sp.
40 *Lepidodendron*, sp.

LIST OF THE FOSSILS FOUND IN THE ARENACEOUS LIMESTONE, OR UPPER BLACK LIMESTONE, NEAR MOLD.

1 *Cladodus*, sp. (teeth of).
2 *Psephodus*, sp. (teeth of).
3 *Steblodus oblongus*, Agass. (teeth of).
4 *Nautilus*, sp.
5 *Bellerophon tenuifascia*, Sow.
6 *Myalina elongata*, ?
7 *Athyris expansa*, Phil.
8 ,, *planosulcata*, Phil.
9 *Productus aculeatus*, Mart.
10 ,, *fimbriatus*, Sow.
11 ,, *giganteus*, Mart.
12 ,, *latissimus*, Sow.
13 ,, *longispinus*, Sow.
14 ,, *Martini*, Sow.
15 ,, *muricatus*, Phil.
16 ,, *punctatus*, Mart.
17 ,, *semireticulatus*, Mart.
18 ,, *Youngianus*, Dav.
19 *Spirifera bisulcata*, Sow.
20 ,, *lineata*, Mart.
21 ,, *trigonalis*, Mart.
22 *Streptorhynchus crinistria*, var. *senilis*, Phil.
23 ,, ,, var. *radialis*, Phil.
24 *Terebratula hastata*, Sow.
25 *Carinella cellulifera*, Eth. Jun.
26 *Chætetes tumidus*, Phil.
27 *Fenestella nodulosa*, Phil.
28 ,, *plebeia*, M'Coy.
29 *Glauconome*, sp.
30 *Palæocoryne*, sp.
31 ,, *Scoticus*.

32 *Rhobdomeson glacile*, Phil.
33 *Archæocidaris Urii*, Flem.
34 *Poteriocrinus crassus*, Koninck.
35 „ *nuciformis*, M'Coy.
36 *Zaphrentis Bowerbanki*, E. & H.
37 „ *Enneskilleni*, E. & H.

LIST OF FOSSILS FOUND IN THE UPPER BLACK LIMESTONE NEAR HOLYWELL.

1 *Patalodus Hastingia*, Owen (teeth of).
2 *Psammodus*, sp. (teeth of).
3 *Steblodus oblongus*, Agass. (teeth of).
4 *Euomphalus*, sp.
5 *Aviculopecten granosus*, Sow.
6 „ *micropterus*, M'Coy.
7 „ *plicatus*, Sow.
8 „ sp.
9 *Pinna flabelliformis*, Mart.
10 *Athyris expansa*, Phil.
11 „ *planosulcata*, Phil.
12 *Chonetes Hardrensis*, Phil.
13 *Crania, sp.*
14 *Discina, nitida*, Phil.
15 *Lingula squamiformis*, Phil.
16 *Orthis Michelini*, Koninck.
17 „ *resupinata*, Mart.
18 *Productus costatus*, Sow.
19 „ *fimbriatus*, Sow.
20 „ *giganteus*, Mart.
21 „ *latissimus*, Sow.
22 „ *longispinus*, Sow.
23 „ *Margaritaceus*, Phil.
24 „ *semireticulatus*, Mart.

25 *Retzia radialis*, Phil.
26 *Rhynchonella pleurodon*, Phil.
27 *Spirifera bisulcata*, Sow.
28 ,, *glabra*, Mart.
29 ,, *lineata*, Mart.
30 *Streptorhynchus crinistria*, Phil.
31 *Terebratula hastata*, Sow.
32 ,, *sacculus*, Mart.
33 *Fenestella Halkinensis*, Shrub.
34 ,, *nodulosa*, Phil.
35 ,, *plebeia*, M'Coy.
36 *Griffithides seminiferus*, Phil.
37 *Serpulites carbonarius*, M'Coy.
38 *Archæocidaris Urii*, Flem.
39 *Pentremites acutus*, Phil.
40 *Poteriocrinus crasssus*, Koninck.
41 *Clisiophyllum turbinatum*, M'Coy.
42 *Cyathophyllum Stutchburyi*, Phil.
43 *Lithostrotion basaltiforme*, Phil.
44 ,, *M'Coyanum*, M. Edw.
45 *Syringopora geniculata*, Phil.
46 *Zaphrentis cylindrica*, Scouler.

The Upper Black Limestone graduates downwards into the Upper Grey Limestone about Holywell. Few fossils have been collected from the latter, for it is only well exposed in Halkin quarry, but a fine specimen of *Orthoceras giganteum* was found there associated with the ordinary fossils found in the subdivision and in the overlying Upper Black Limestone.

CARBONIFEROUS LIMESTONE OF THE EXTREME NORTH OF FLINTSHIRE.*

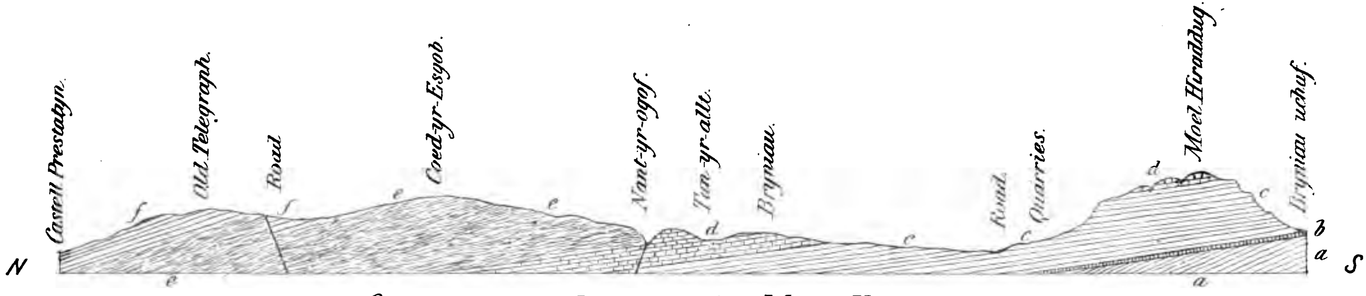
THE Carboniferous Limestone is well developed in the North of Flintshire, where it is close to the village of Prestatyn, a station on the Chester and Holyhead Railway. The limestone hills are bounded on the north and west by a low sandy plain, on which the town of Rhyl is situated, at a distance of about four miles from Prestatyn. The hills rise with precipitous sides to an elevation of 600 feet, and form an elevated plateaux from which a magnificent view of the coast of North Wales is obtained. The highest points are the Old Telegraph, 769.8 feet; St. Elmo's Summer House, 782.8 feet; Coed-yr-Esgob, 695.6 feet; the Tumulus on Gop Hill, Newmarket, 819.7 feet; and Moel Hiraddug, 866.5 feet. The subdivisions of the Carboniferous Limestone are all well exposed within three miles from Prestatyn. The picturesque villages of Gwaenysgor

* Since this Paper was read a new edition of the Geological Survey Map, Quarter Sheet, 79 N.W., has been issued, and an Explanation of it, "The Geology of the Coasts adjoining Rhyl, Abergele, and Colwyn," by Mr. Aubrey Strahan, M.A,, F.G.S., has been published. The subdivisions of the Carboniferous Limestone, as described by me, are referred to, and some lists of fossils fully acknowledged, but the actual details respecting the area included in the Map are now published for the first time. All interested in the geology of the district should procure the Map and Explanation of it, which contain much valuable information, the result of Mr. Strahan's observations. There are descriptive details of all the formations contained within the limits of the Map, and a full account of the Economic Geology, Faults, Mines, and Minerals, with a sketch-map and sections of the Talargoch Mine and neighbourhood. There is also a "List of Works on the Geology, &c., of Denbighshire and Flintshire," by Mr. William Whitaker, B.A., F.G.S.

and Newmarket on the plateaux, and Dyserth and Meliden at the base, are in such close proximity, that the examination of the district is unusually easy. Two miles from Prestatyn are the ruins of Dyserth Castle and Siamber-wen, the latter a ruinous building resembling a church, but supposed by Pennant to have been the seat of Sir Robert Pounderling, once constable of the adjacent castle. There is a waterfall at Dyserth in a rocky gorge, and the water is derived from St. Asaph's Well in a dingle about a mile to the east. The numerous tumuli are remarkable, and, according to Pennant, the district must have been for ages a battlefield of contending forces, which only terminated with the civil war of the 17th century.

The Cefn-y-Fedw Sandstone extends for a mile to the south-west of Gronant, and the Cherty Sandstone at its base finally crops out between Prestatyn and Llanasa, so that this formation, so fully described as traversing the country for about 40 miles, requires no further comment. It may be represented by the Millstone Grit of the country on both sides of the Menai Straits; but if it ever existed over the intervening area, it has been entirely denuded.

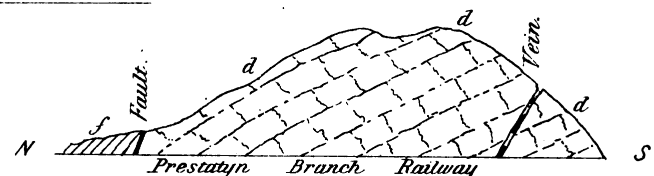
The Carboniferous Limestone ends with such a steep escarpment towards the north-west, that it presents a magnificent section of the four subdivisions into which it is divided by distinct lithological characters. The section (Plate 2), across the strike of the strata shows the contour of the hills, the relative position of the subdivisions, and the thickness of each. The length of the actual section is nearly four miles from Castell Prestatyn on the north, to the south end of Moel Hiraddug, near Cwm. The following table shows that the Carboniferous Limestone is 1,700 feet thick, which is much greater than anywhere else in North Wales.



Section from Prestatyn to Moel Hiraddug.

PLATE 2.

f	Upper Black Limestone,	200	feet
e.	Upper Grey Limestone,	500	„
d.	Middle White Limestone,	600	„
c.	Lower Brown Limestone,	400	„
b.	Red Basement Beds,	?	„
a.	Wenlock Shale.	?	„
		1,700	„



Graig fawr.

SUBDIVISIONS OF THE CARBONIFEROUS LIMESTONE OF THE EXTREME NORTH OF FLINTSHIRE.

Subdivision.	Thickness in feet.	Locality where well exposed.
Upper Black Limestone ...	200	Prestatyn and Llanasa.
Upper Grey Limestone ...	500	Coed-yr-Esgob and Gwaenysgor.
Middle White Limestone...	600	Graig-fawr and Dyserth.
Lower Brown Limestone...	400	Moel Hiraddug and Marian-cwm.
	1,700	

UPPER BLACK LIMESTONE.

The Upper Black Limestone, the highest subdivision, crops out on the north of the hill east of Prestatyn, and is well exposed in several quarries on the road leading up to the Old Telegraph and Gwaenysgor. There are several faults, as shown on the Geological Survey Map, so that the dip varies from 10° to 16° W.W.S., N.E., and N.N.E., but the general inclination is towards the north. The strata consist of a very uniform series of black, fine grained, thin-bedded limestone separated by frequent partings of shale throughout its entire thickness, with occasional beds of the latter. It resembles the "Aberdo Limestone" at Halkin, but is not such a solid rock, being divided vertically by numerous joints, and breaking up into long splintery fragments. The surfaces of both the beds and the joint-planes are weathered to a light brown, so that it is necessary to break the rock to see the internal dark colour. It was formerly worked for making hydraulic cement, but the works on the shore have been closed some years. The Upper Black Limestone about Prestatyn does not contain the thick interstratified beds of

grey limestone with *Productus giganteus*, which are so conspicuous in the subdivision at Halkin. The base of the Upper Black Limestone is exposed in a quarry at Teilia, a quarter of a mile north-east from Gwaenysgor, where it rests on the Upper Grey Limestone. It was in this quarry that the late Mr. J. B. Shone, of Chester, collected several species of ferns and other plants from some sandy calcareous flags forming the base of the subdivision, and they are now in the Museum of the Society of Natural Science, at Chester. Associated with the plants are other species obtained by Mr. A. Strahan, F.G.S., and myself, and appended in a list of the fossils. It has not been possible to obtain the exact thickness of the Upper Black Limestone about Prestatyn, but it is probably about 200 feet as at Halkin. It is again exposed in a quarry at Ty-drau, near Llanasa, where it presents the same lithological characters and dips 16° N.N.E. The absence of the brachiopoda in the Upper Black Limestone about Prestatyn is very remarkable, especially as they are so numerous at Halkin. The original deposit was a calcareous mud, and rapid deposition may account for so few organic remains being found. The plants and teeth of fishes occur only at the base of the subdivision.

The following is a list of the fossils that have been found in the Upper Black Limestone. They were all found at Teilia quarry—and only the species of *Aviculopecten* and *Posidonomya*, on the Old Telegraph Hill and on the road leading up to it from Prestatyn.

LIST OF FOSSILS FOUND IN THE UPPER BLACK LIMESTONE AT TEILIA, NEAR GWAENYSGOR.

1 *Cladodus*, sp. (teeth of).

2 Coprolite of fish (? *Megalichthys*).

3 *Orthoceras*, sp.

4 *Goniatites bilinquis*, Salt.
5 *Aviculopecten papyraceus*, Goldf.
6 *Posidonomya Becheri*, Goldf.
7 ,, *Gibsoni*, Brown.
8 *Sedgwickia ?* fragments.
9 *Zaphrentis*, small sp.

PLANTÆ.

10 *Adiantites Lindsæiformis*, Salt.
11 *Calamites, pachyderma*, Brong. (or *nodosus*, a coarse variety.)
12 *Hymenophyllites furcata*, Gopp.
13 ,, *dissecta* (?) Gopp.
14 *Sphenopteris affinis*, Lind.
15 ,, *artemisifolia*, Sternb.
16 ,, *crithmifolia*, Lind.
17 ,, *Honinghausii* (?) Brong.
18 ,, *linearis*, Sternb.
19 ,, *stricta*, Brong. (?)
20 ,, *trichomanoides*, Brong.
21 *Staphylopteris* (?)

UPPER GREY LIMESTONE.

The Upper Grey Limestone is well developed in the north of Flintshire and may usually be found cropping out from under the Upper Black Limestone, where the strata are exposed at the surface. It is a thin-bedded dark grey limestone, and forms the hill above Prestatyn, known as Coed-yr-Esgob, as shown in the section (Plate 2). Along the base of this hill the limestone is well exposed in four or five quarries, and occurs in beds from one to two feet thick and of a dark grey colour, though the weathered face of the rock is white. The strata dip at various angles from 14° to 18° to the N.E. and N.N.E.

and are interstratified with thin seams of black shale. The limestone in all the quarries is of a similar lithological character, but in the most northern one, nearest to Prestatyn, where the highest beds are exposed, there are a few thin bands of chert. There is a remarkable mineral vein from four to six feet wide filled with calcite, which projects from the quarry, for the limestone has been removed from each side, and it presents a fine example of such a vein; though I am not aware that galena, or any other mineral, except the calcite, has been found in it. Near the bottom of the most southern quarry, in a hard seam of black shale a few inches thick, I found numerous teeth of fishes forming a thin bone-bed, but they are all of the same species, *Cladodus mirabilis*, Agass, as determined by Mr. W. Davies, F.G.S., of the Natural History Museum, South Kensington. In the beds just over the bone-bed the following species occur :—*Goniatites sphæricus*, *Orthis resupinata*, *Productus semireticulatus*, *Spirifera bisulcata*, *S. glabra*, and an undetermined coral. On the plateaux over the crest of the hill, about the village of Gwaenysgor, the Upper Grey Limestone is exposed in several quarries, *Chonetes papilionacea*, *Orthis resupinata*, *Productus giganteus*, *P. semireticulatus* and *Syringopora geniculata* are of common occurrence. It is also well exposed in some quarries worked along the strike of the beds on the south-east of Gop Hill at Newmarket, where the dip is 14° N.E., and the following fossils occur :—*Euomphalus Dionysii*, *Athyris Royssii*, *Chonetes papilionacea*, *Productus aculeatus*, *P. cora*, *P. giganteus*, *P. punctatus*, *P. semireticulatus*, *Spirifera bisulcata*, *Streptorhynchus crinistria*, and *Lithostrotion Martini*. The highest beds occur at Bryn-yr-odyn and dip 8° E.N.E. in a quarry where I found *Spirifera cuspidata*, and which also occurs at

Axton. The same beds are again exposed at the base of Teilia quarry already described.

The Upper Grey Limestone is well exposed in several quarries on Axton Hill, where the strata are near the top of the subdivision. The Axton limestone, however, is of a lighter grey than usual and remarkably fossiliferous. The beds dip 32° N.N.W. in quarries near Penllan and Plas-gwyn, but only 18° at the west end of the hill. Besides the quarries there are many small excavations all along the strike of the same beds, which do not seem to exceed 50 feet in thickness. The numerous fossils and the perfect condition in which they occur, with the occurrence of many species, which I have not found elsewhere in Denbighshire or Flintshire, render Axton one of the most interesting localities for Carboniferous fossils in North Wales.

The thickness of the Upper Grey Limestone is altogether about 500 feet,† and the base can be seen in the ravine, Nant-yr-ogof, as shown in the Section (Plate 2). The following is a full list of the fossils from the Axton Limestone containing some additional species to my original list published in "The Geology of the Coast adjoining Rhyl, Abergele and Colwyn," by Mr. A. Strahan, M.A., F.G.S.

LIST OF FOSSILS FOUND IN THE UPPER GREY LIMESTONE AT AXTON, NEAR NEWMARKET.

1 **Nautilus phanotergatus*, M'Coy (= *Discites Lavellianus*, Koninck).

2 **Orthoceras*, new sp.

3 *Bellerophon*, sp.

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† The Upper Grey Limestone at Prestatyn probably includes some portion of the Upper Black Limestone at Holywell, where the "Aberdo Limestone" is interstratified with thick beds of grey limestone containing *Productus giganteus*.

4 *Buccinum rectilineum*, Phil.
5 *Euomphalus Dionysii*, Goldf.
6 ,, *pentangulatus*, Sow.
7 **Littorina* ? new sp.
8 *Loxonema*, sp.
9 *Macrocheilus imbricatus*, Sow.
10 *Natica ampliata*, Phil.
11 *Nerita spirata*, Sow.
12 *Pleurotomaria rotundata*, Sow.
13 *Porcellia Puzosi*, Koninck.
14 *Straparollus costellatus*, M'Coy.
15 *Ambonychia undata*, Hall.
16 **Aviculopecten circularis*, Koninck.
17 * ,, *fimbriatus*, Sow.
18 ,, sp.
19 *Edmondia unioniformis*, Phil.
20 *Sanguinolaria*, sp.
21 *Athyris expansa*, Phil.
22 ,, *planosulcata*, Phil.
23 ,, *Royssii*, Lév.
24 **Discina nitida*, Phil.
25 **Orthis Keyserlingiana*, Koninck.
26 ,, *resupinata*, Mart.
27 **Productus aculeatus*, Mart.
28 ,, *cora*, D'Orb.
29 ,, *costatus*, Sow.
30 ,, *fimbriatus*, Sow.
31 ,, *giganteus*, Mart.
32 ,, *latissimus*, Sow.
33 ,, *longispinus*, Sow.
34 * ,, *plicatilis*, Sow.
35 ,, *punctatus*, Mart.
36 * ,, *pustulosus*, Phil.
37 ,, *semireticulatus*, Mart.

38 *Productus striatus*, Fischer.
39 **Rhynchonella acuminata*, Mart..
40 ,, *pleurodon*, Phil.
41 * ,, *pugnus*, Mart.
42 *Spirifera bisulcata*, Sow.
43 * ,, *convoluta*, Phil.
44 ,, *cuspidata*, Mart.
45 * ,, *duplicicosta*, Phil.
46 ,, *glabra*, Mart.
47 * ,, *grandicostata*, M'Coy.
48 * ,, *integricosta*, Phil.
49 ,, *pinguis*, Sow.
50 ,, *lineata*, Mart.
51 * ,, *ovalis*, Phil.
52 ,, *striata*, Mart.
53 ,, *subconica*, Mart.
54 ,, *triangularis*, Mart.
55 *Streptorhynchus crinistria*, Phil.
56 *Terebratula hastata*, Sow.
57 *Fenestella plebeia*, M'Coy.
58 *Pinnatopora*, sp.
59 *Griffithides seminifera*, Phil.
60 *Poteriocrinus crassus*, Koninck.
61 **Amplexus coralloides*, Sow.
62 *Syringopora geniculata*, Phil.
63 *Zaphrentis Griffithi*, E. and H.

The occurrence of so many species peculiar to the Upper Grey Limestone at Axton seems to indicate that they migrated from some locality outside the present North Wales Carboniferous area, and had not time to spread beyond the limited district in which they are found before such sedimentary changes occurred as to

* The species thus marked have not been recorded by me in North Wales before.

cause their local extinction. Another local species, *Spirifera cuspidata*, Mart., occurs as already stated at Bryn-yr-odyn; and in addition to the many common species, *Goniatites sphæricus*, or *G. crinistria*, occurs in the most southern quarry at Coed-yr-Esgob, a rare North Wales species, of which I found one specimen near Erryrys, Llandegla, and saw another said to have been found in the Upper Grey Limestone at Llangollen. Some species in the lists may be only varieties of others, and *Spirifera bisulcata*, *S. grandicostata* and *S. trigonalis* may all be varieties of one species; but at Axton they are so distinct that they are retained under their original names. I was indebted to the Rev. F. Splain, S.J., for informing me of the fossiliferous character of the Axton limestone as early as 1867, and the fossils in the list have been collected at intervals since that year.

MIDDLE WHITE LIMESTONE.

The Middle White Limestone is well exposed in many quarries and natural sections in the country between Holywell and Dyserth. A fine exposure occurs in a large quarry on the west of Coed-y-Garreg, a hill with an ancient beacon or watch-tower on the summit, which is 808.6 feet above ordnance datum. The limestone forms thick beds of a light grey colour, dips 8° N.N.E., and is of the usual unfossiliferous character. There are many other quarries on the road to Llyn Helyg and Newmarket, and some natural exposures on the surface. The subdivision is well exposed in the precipitous hills between Meliden and Dyserth, and there are fine sections of it at Nant-yr-ogof, Bryniau, Dyserth Castle, the rocky ground about Dyserth Waterfall, and Graig-fawr, the commanding eminence near Meliden, and there is a general dip of the strata towards the north in all these places. It

also occurs on the highest part of Moel Hiraddug, along two-thirds of the top from the south, being gradually denuded on the dip towards the north-east, and the greatest thickness not exceeding 150 feet; but the great mass of that conspicuous hill is composed of the Lower Brown Limestone, which probably rests unconformably on the Wenlock Shale.

The section (Plate 2) shows the position of the Middle White Limestone in relation to the other subdivisions of the limestone. A great fault, named by Mr. Strahan the Prestatyn fault, runs nearly north and south from Castell Prestatyn to Tan-yr-allt, with a down-throw of several hundred feet to the west, and at the latter place it either ends or becomes of little importance. Another important fault, probably a branch from the Prestatyn fault, runs up the ravine at Nant-yr-ogof, crossing the line of section, and throws up the lower beds of the Middle White Limestone, and also exposes the Lower Brown Limestone. There are large quarries at Bryniau, where similar beds of the Middle White Limestone occur, and further south the base of the subdivision crops out, and the Lower Brown Limestone continues to Moel Hiraddug.

Although there are several veins and small east and west faults intersecting the section, none of any importance, excepting that at Nant-yr-ogof, have been observed. From Castell Prestatyn to Meliden, however, there is a flat plain of drift on the west side of the Prestatyn fault, but near Meliden the Upper Black Lmestone is thrown up to the surface, and occurs in the underground works of the Talargoch lead-mine. The thin-bedded black limestone of the subdivision may be seen in several old quarries about Tan-yr-allt, on the west side of the Prestatyn fault, and the Middle White

Limestone rises in an abrupt cliff on the east side of the fault. South of this place the Middle White is on both sides of the fault, the continuance of which is obscure. Another fault, of almost equal importance, occurs between the Upper Black and the Middle White Limestone along the northern base of Graig-fawr, and as the subdivisions are exposed on each side, its position may be traced within a few yards. It is, however, actually visible in an old quarry a few yards west of Tan-yr-allt, where it is filled with limestone breccia from 15 to 20 feet in width, with the Upper Black on the north-east and the Middle White Limestone on the south-west side of the fault. The amount of dislocation caused by this fault must be 600 feet, for the whole of the Upper Black and Upper Grey Limestone have been denuded on the south-west side of it. The former subdivision is exposed in several places, and dips 30° to 45° to the N. and N.N.E., while the highest beds of the Middle White Limestone, on the south-west, are exposed the whole length of the fault, with an average dip of about 25° to the north or north-east, excepting where the beds bend down to a greater angle close to it. This fault may be named the Graig-fawr fault. It runs into the Prestatyn fault on the east at Tan-yr-allt, and ends on the west against a fault shown on the Geol. Surv. Map N.N.E. by S.S.W., close to the railway at the extreme north point of Graig-fawr. From observations made underground in the Talargoch Mine, Mr. Strahan has discovered several faults, particularly a great north and south fault, bringing in the Lower Coal-measures, on the west of Graig-fawr, and which he considers to be a continuation of the Vale of Clwyd fault.

Although the Middle White Limestone occurs in the localities already referred to, it is much better exposed

in Graig-fawr than anywhere else, for the hill is a bare precipitous limestone rock, 500 feet high, or 300 feet above the railway, so that every bed may be examined, and it seems to present the whole of the subdivision, and to be at the least 600 feet in thickness. The limestone is of a very massive character, and there are so few bedding-planes that the northern dip cannot be determined with exactness, for the whole seems like one great bed, traversed by mineral veins, jointed and shattered by the influence of the great faults so close to it. At the north end of the hill, where the highest beds are exposed, there are numerous fossils, but below these there are few to be found, and only *Chonetes papilionacea, Productus cora* and *Encrinite* stems have been recorded. The limestone is all of a white or light grey colour, with the exception of some rather darker beds towards the base on the south side of the hill. Several mineral veins traverse the precipitous cliffs on the south end of the hill, one of which hades to the north, and seems the most important. They have all been worked and the contents removed, and show the mode in which such veins, or lodes, were worked from the surface.

The fossiliferous beds at the north end of Graig-fawr have been traced half-way up the hill and a little distance along the railway, but they might not have been noticed if the rock had not been recently quarried.

LIST OF FOSSILS FOUND IN THE MIDDLE WHITE LIMESTONE AT THE NORTH END OF GRAIG-FAWR.

1 *Nautilus*, sp.
2 *Orthoceras*, sp.
3 *Euomphalus pentangulatus*, Sow.
4* ,, *pileopsideus*, Phil.
5 *Macrochilus imbricatus*, Sow.

6 *Nerita spirata*, Sow.
7 *Pleurotomaria rotundata*, Sow.
8 ,, sp.
9 *Porcellia Puzosi*, Koninck.
10 *Ambonychia undata*, Hall.
11* *Aviculopecten planoradialis*, M'Coy.
12* *Cardiomorpha oblonga*, Sow.
13* *Cucullea arguta*, Phil.
14 ,, sp.
15 *Edmondia unioniformis*, Phil.
16 *Myacites sulcata*, Flem.
17 *Pinna flabelliformis*, Mart.
18 *Productus cora*, D'orb.
19 ,, *fimbriatus*, Sow.
20 ,, *giganteus*, Mart.
21 ,, *longispinus*, Sow.
22 ,, *Margaritaceus*, Phil.
22 ,, *punctatus*, Mart.
24* ,, *scrabriculus*, Mart.
25 ,, *semireticulatus*, Mart.
26 ,, *striatus*, Fisch.
27 *Spirifera bisulcata*, Sow.
28 ,, *glabra*, Mart.
29 ,, *lineata*, Mart.
30 ,, *pinguis*, Mart.
31 ,, *striata*, Mart.
32 ,, *subconica*, Mart.
33 *Streptorhynchus crinistria*, Phil.
34* *Rhynchonella angulata*, Linn.
35 ,, *pleurodon*, Phil.
36 *Terebratula hastata*, Sow.
37 *Griffithides seminiferus*, Phil.

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* The species thus marked have not been recorded by me in North Wales before.

Productus giganteus in this list is only represented by a few young specimens, whereas, in the Upper Grey Limestone at Axton it is very abundant.

LOWER BROWN LIMESTONE.

The Lower Brown Limestone is fully exposed in the steep flanks of Moel Hiraddug (Plate 2), which presents a fine section about 500 feet in thickness. The Middle White Limestone, which forms the highest part of the hill, is about 150 feet, and the underlying Lower Brown Limestone 400 feet, though no very precise line of separation can be drawn between them. The latter subdivision consists of a uniform series of beds of brown semicrystalline limestone. With the exception of the base, the whole subdivision is exposed in the precipitous cliffs at the north of Moel Hiraddug, and the large quarry at that end of the hill which is close to Dyserth. The beds are usually from 1 to 4 feet in thickness, and dip at an angle of 14° N.N.E., merely separated by bedding-planes without any shale between them. Fossils are not numerous, though the following species have been collected and identified.

LIST OF FOSSILS FOUND IN THE LOWER BROWN LIMESTONE OF MOEL HIRADDUG.

1 *Bellerophon*, sp.
2 *Euomphalus tabulatus*, Sow.
3 ,, *Dionysii*, Goldf.
4 *Chonetes papilionacea*, Koninck.
5 *Productus cora*, D'Orb.
6 ,, *giganteus*, Mart.
7 ,, *punctatus*, Mart.
8 *Spirifera elliptica*, Phil.
9 ,, *lineata*, Mart.
10 *Streptorhynchus crinistria*, Phil.
11 *Cyathophyllum Murchisoni*, M. Edw.
12 *Syringopora*, sp.
13 *Zaphrentis cylindrica*, Scouler.

Some were obtained from the hill-side, but most from the quarry, and in some of the lowest beds that are worked very large specimens of *Euomphalus tabulatus* and *Productus giganteus* were seen embedded in the limestone.

The lowest beds of the Lower Brown Limestone present the typical character of the subdivision at Nannerch and other places further south, in Flintshire and Denbighshire, and are exposed in an old quarry between Pentre-bach and Pentre-cwm on the south-west of Moel Hiraddug. In 1870 I described this base of the Carboniferous Limestone, with the plants and other fossils that occur in the quarry.* The strata consist of beds of brown limestone, several feet thick, of a very variable character, and frequently change into a brownish sandstone. They alternate with seams of thin limestone and interstratified brown shale, containing numerous remains of plants. The thickness of these shaly beds does not seem to exceed 40 feet, but the base is not visible, and as they do not appear anywhere else they may be the very lowest beds of the Lower Brown Limestone under Moel Hiraddug. It is, however, possible that the interstratified shale may be of local occurrence.

The fossils are not numerous, and in such a bad state of preservation that it is often difficult to determine the species. The occurrence of plants renders the following list interesting :—

LIST OF FOSSILS FROM THE BASE OF THE LOWER BROWN LIMESTONE AT PENTRE-BACH, MOEL HIRADDUG.

1 *Athyris Royssii*, Lév.
2 *Spirifera lineata*, Mart.
3 *Syringopora*, sp.

* British Association Report for 1870. Trans. of Sections, p. 82.

4 *Zaphrentis*, sp.
5 *Lepidodendron* (?)
6 *Sphenopteris* (?)

On the summit and flanks of Moel Hiraddug, hæmatite has been obtained from an early period, and it occurs in large cavernous pits with steep sides. The ore forms nodules in red clay, and a great quantity has been obtained in recent years. Associated with the hæmatite, cobalt and nickel occur, and have been worked since 1870 on Moel Hiraddug, which is the only locality in the British Isles where cobalt is now obtained. The following is a list of the minerals found in the north of Flintshire :—

Aragonite.	*Blend.*
Calamine.	*Galena*, often argentiferous.
Calcite.	*Hæmatite*, with *cobalt*, *copper*, and *nickel*.
Cerusite.	*Petroleum.*
Chalcopyrite.	*Pyrite.*
Beekite.	*Quartz*, in minute grains.

RED BASEMENT BEDS.

Below the Lower Brown Limestone on the south-west of Moel Hiraddug there are probably some red strata, which were formerly considered to represent the Old Red Sandstone, but now to be the base of the Carboniferous Series. Near Pentre-cwm, on the north side of the road, and a little higher up the hill, a heap of red clay may be seen about the site of an old shaft, evidently sunk through the Boulder Clay. The clay contains numerous worn fragments of hard shale, probably Wenlock Shale, covered with peroxide of iron, but there is no exposure of the strata, for there is a deep fringe of Boulder Clay

over the surface along the side of the hill. Nearly a mile to the east, about the Cwm iron-mine, the Lower Brown Limestone occurs at the surface, and is in many places covered with a red clay mixed with fragments of shale, the refuse from mining operations. It fills fissures and forms heaps around the numerous shafts and cavernous trenches from which hæmatite has been obtained, but the mines are now deserted. At Marian-bach the clay and shale seem to be at the base of the limestone, but in such a disturbed condition that it is impossible to arrive at a satisfactory conclusion. Similar red clay has been thrown out from excavations on the top of Moel Hiraddug, where hæmatite has been obtained from the Middle White Limestone.

It seems, however, probable that the Red Basement Beds may be represented at the base of the Lower Brown Limestone, but in the absence of any clear sections it may be only by pebbles and fragments of shale coloured by peroxide of iron.*

I have elsewhere shown that beds of red shale, sandstone and conglomerate frequently underlie the Carboniferous Limestone at whatever horizon happens to rest on the Silurian rocks beneath, and are sometimes interstratified with it.†

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* Mr. A. Strahan, in "The Geology of the Coasts adjoining Rhyl, Abergele, and Colwyn," previously referred to, is of opinion that the Red Basement Beds do occur in this locality, and states that the thickness between Pentre-bach and Pentre-cwm is 95 feet, west of Marian-bach 50 feet, while at Marian the beds have thinned out, the rate of attenuation being about 1 in 55.

† "The Carboniferous Limestone of North Wales," "Llanymynech Hill," p. 114, also "Proceedings of Liverpool Geological Society," vol. iii., p. 403. The conglomerate, however, was found since these were written.

The abrupt termination of the Carboniferous Limestone in the north of Flintshire is one of the most interesting features in the Geology of the country described. The surface presents an ever-varying aspect along the country, until near Prestatyn and Dyserth, where the limestone is thrown down below the sea level by the Prestatyn, Graig-fawr, Vale of Clwyd and other faults. The level plain between the hills and the sea is composed of a great thickness of drift, and a mining shaft recently sunk close to the base of Coed-yr-Esgob passed through 204 feet of sand, and had to be given up without reaching the rock, or the vein it was expected to reach. Many other borings have been made, and all prove the great thickness of drift over the flat area at the west of the hills. The influence of the great faults throwing down the limestone is conspicuous in many minor faults and mineral veins, which intersect the limestone and run off the main faults at various angles, indicating the enormous strain caused by the dislocation of the strata.

The occurrence of the Lower Coal-measures far below the surface in the workings of the Talargoch mine proves a considerable down-throw of the Carboniferous Limestone, probably to the extent of 1,500 feet, though it must vary in different places—the faulting being of a very complicated nature, and only partially accessible for examination.

Sir A. C. Ramsay, F.R.S., in the 2nd edition of his "Geology of North Wales," p. 309, refers to the subject as follows:—

"On the down-throw side of the great fault which forms the western boundary of the Carboniferous Limestone at Diserth, shale containing a thin bed of coal, and dipping N.W., has been found in the workings of

the Talargoch lead-mine, and the same beds dipping N. have been found near Meliden. The dip of the strata in both places would lead to the assumption that higher and more profitable Coal-measures might be met with in a north-westerly and northerly direction before reaching the sea. In anticipation of this being the case, a bore-hole was made at Foryd, near Rhyl. The following details were given to Mr. Strahan, of the Geological Survey, by Mr. Leigh Howell, of Bagillt, and they throw considerable light on the subject." The section obtained from the boring is then given, and the following is the condensed abstract of it:—

	YDS.	FT.	IN.	
Post Glacial Deposits ...	17	2	10	
Glacial Deposits	14	2	2	
New Red Sandstone......	166	1	0	
Probably Carboniferous Strata.....................	49	2	5	
	248	2	5	=746½ feet.

It is obvious that faults throwing the Carboniferous Limestone, with a northerly dip, down to the west would bring the overlying Cefn-y-Fedw Sandstone and Coal-measures further south along the west of the faults, and it is very likely that some of the higher Productive Coal-measures come in to the north-west as stated. But as the boring at Foryd, the mining shaft near Coed-yr-Esgob, and some other borings at Prestatyn all prove such a great depth of drift, it would be a difficult undertaking to work any coal that might be discovered by boring, unless a locality could be found where the Coal-measures are near the surface.

Both north and west of Graig-fawr there are two considerable faults, and in both directions the Upper

Black Limestone is thrown down against the Middle White Limestone, and then second faults bring in the Lower Coal-measures against the Upper Black Limestone, but the former have caused the greatest displacement of the strata. It does not seem that any portion of the Cherty Sandstone, or Gwespyr Sandstone, occurs in the mine workings.

The Lower Coal-measures have been found, not only underground at Talargoch, but in mining operations at Dyserth, and Mr. Strahan observed the following section at the depth of 540 feet from the surface, close to the shaft, in a cross-cut from the South Joint vein, between Graig-fawr and Meliden:—

	FT.	IN.
Metal, or shale	10	0
Coal	0	5
Splintery metal	1	2
Coal	0	3
Metal	2	0
	13	10

The shale contained bivalve shells and numerous stems of *Calamites* and other plants. Mr. Strahan is of opinion that a strip of Lower Coal measures, brought in by the Vale of Clwyd fault, runs in front of the Middle White Limestone cliff at Dyserth, over which the Waterfall flows, and that it extends about two miles to the southwards, as shown on the recent issue of the Geological Survey Map of the district.

CONCLUSION.

In concluding this description of the Carboniferous Limestone and Cefn-y-Fedw Sandstone of Flintshire, I may now give the results of many years' observations over Denbighshire and Flintshire in a condensed form.

The examination of the narrow area, from 1 to 5 miles in width, and with some insignificant breaks in continuity 44 miles in length, has proved the lithological characters of the subdivisions of the Carboniferous Limestone to be remarkably persistent over its whole extent. The lines of separation may not always be exactly on the same horizon, but the clear and distinct character of each subdivision is so pronounced as to give reality and permanent importance to the classification.

All along the country described the succession of the subdivisions has been obvious, and the similarity between the whole series at Llangollen in the south and Prestatyn in the north is very remarkable—with the exception of the Arenaceous Limestone of the former, and the Upper Black Limestone of the latter, which, although on the same horizon and forming the highest subdivision in each district, differ very considerably. The more shaly character of the Lower Brown Limestone at Llangollen, compared with the same subdivision at Moel Hiraddug, where the interstratified shale only occurs in the lowest portion, is another change that has been observed, especially north of Mold; but it is only at the extreme north and south of the limestone area described that there is the greatest downward development.

The Cefn-y-Fedw Sandstone includes all the strata between the Carboniferous Limestone and the Lower Coal-measures. It may include the Yoredale Series and the Millstone Grit, and a new name was given to the strata occupying this position in North Wales, because of a difference of opinion that prevailed as to which of those formations it represented. Whatever the exact equivalent of the Cefn-y-Fedw Sandstone may be, it has been found to have so completely changed in lithological character from south to north as only to be recognized from its stratigraphical position, about which there can be no doubt.

There has been a regular and continued deposition from the Lower Brown Limestone up to the Coal-measures, consequently there is no instance of unconformity throughout the whole Lower Carboniferous Series in North Wales. The thickness of the limestone, however, varies with the original surface undulations of the underlying Silurian rocks, which seem to have been the deepest where the Carboniferous Limestone is now the thickest.

It is probable that the whole of the Carboniferous Limestone and Cefn-y-Fedw Sandstone, and perhaps even the Coal-measures, may have covered the Moel Fammau range of hills, as originally suggested by Sir A. C. Ramsay; but the limestone covered only the lower portion, and left the hills of Wenlock Shale exposed.

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* Have read Papers before the Society.
† Contribute annually to the Printing Fund.

CONTENTS.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE TWENTY-EIGHTH,

1886-7.

EDITED BY W. HEWITT, B.SC.

(*The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.*)

PART III.—VOL. V.

LIVERPOOL:

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1887.

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LIVERPOOL GEOLOGICAL SOCIETY,

IN ACCOUNT WITH

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OCTOBER 12TH, 1886.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

(*Publications have been received in exchange during the Session from those marked* *)

*Academy of Natural Sciences, Philadelphia.
Advocates' Library, Edinburgh.
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* Do. Literary and Scientific Society.
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*Bristol Naturalists' Society.
*Bodleian Library, Oxford.
*Boston Society of Natural History, U.S.
*Chester Society of Natural Science.
Dudley and Midland Geological and Scientific Society.
*Essex Naturalists' Field Club.
Editor of "Geological Record."
,, "Nature."
,, "Geological Magazine."
,, "Science Gossip."
Ertborn, Le Baron O. Van, Anvers, Belgique.
*Geological Society of Edinburgh.
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Geological Society of London.
*Geological Society of Manchester.
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*Geological Society of Australasia, Melbourne.
*Geological Survey of the United States.
Geological Survey of India.

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PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-EIGHTH.

OCTOBER 12TH, 1886.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair.

The Officers and Council for the ensuing year were elected. The Treasurer submitted his Statement of Accounts.

The President then read his Annual Address:—

EARLY LIFE ON THE EARTH.

NOVEMBER 9TH, 1886.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair.

Mr. D. MACKINTOSH, F.G.S., was elected an Honorary Member, and Mr. W. RHEAM, B.Sc., and Mr. S. J. PALMER, M.B., were elected Ordinary Members of the Society.

The following communication was read:—

THE SURFACE CONFIGURATION OF THE MOON.
By D. MACKINTOSH, F.G.S.

DECEMBER 14TH, 1886.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair.

Mr. E. NEWALL was elected an Ordinary Member of the Society.

The Reports on the Field Meetings were read as follows:—Bidston and Oxton, by H. C. Beasley; Thurstaston, by O. W. Jeffs; Eastham, by the President; Prestatyn, by the President.

The following papers were read:—

ON THE OCCURRENCE OF INTERNAL CALCAREOUS SPICULES IN POLYZOA.

By J. Lomas, Assoc.N.S.S.

NOTE ON THE CARBONIFEROUS LIMESTONE FISHES OF NORTH WALES.

By G. H. Morton, F.G.S.

JANUARY 11th, 1887.

The President, G. H. MORTON, F.G.S., in the Chair.

The following papers were read:—

SOME INSTANCES OF HORIZONTALLY STRIATED SLICKENSIDES.

By H. C. Beasley.

THE CALDAY-GRANGE FAULT, AND OTHERS NEAR WEST KIRBY.

By O. W. Jeffs.

FEBRUARY 8th, 1887.

The President, G. H. MORTON, F.G.S., in the Chair.

The following papers were read:—

NOTES ON THE EXCAVATIONS FOR THE PRESTON DOCKS.

By E. Dickson.

ON THE OCCURRENCE OF COPPER IN THE BUNTER CONGLOMERATE OF HUNTINGTON, STAFFORDSHIRE.

By A. Timmins, C.E.

A SECTION OF BOULDER CLAY, NEAR HYDE, CHESHIRE.

By J. Lomas, Assoc.N.S.S.

MARCH 8th, 1887.

The President, G. H. MORTON, F.G.S., in the Chair.

Mr. P. Holland, F.C.S., was elected an Ordinary Member of the Society.

The following papers were read:—

SOME USES OF THE CARBONIFEROUS LIMESTONE.

By J. J. Fitzpatrick.

THE BASE OF THE CARBONIFEROUS LIMESTONE.

By Dr. C. Ricketts, F.G.S.

THE MICROSCOPIC CHARACTERS OF THE MILL-STONE GRIT OF SOUTH-WEST LANCASHIRE.

By G. H. Morton, F.G.S.

APRIL 19th, 1887.

The President, G. H. MORTON, F.G.S., in the Chair.

The following paper was read:—

IRON AS A COLOURING MATTER OF ROCKS.

By A. Norman Tate, F.I.C., F.C.S.

[PRESIDENT'S ADDRESS.]

EARLY LIFE ON THE EARTH.

By G. H. MORTON, F.G.S., F.R.G.S.I.

AFTER the lapse of 16 years it again becomes my privilege to address you as president of this Society. During that period there has been a considerable change in the members who attend our meetings and take an active part in our proceedings, though it is gratifying to know that those who are now absent have left us in consequence of ordinary causes, and that for the most part they still take an interest in the welfare of the Society. Our losses have been greater with the Honorary Members, for early this year Prof. John Morris, F.G.S.,* and Prof. W. King, D.Sc.,† were taken from the scene of their labours, though both had attained an advanced age.

Since my last address we have added many new members to our roll, and it is gratifying to find that four of them have been elected President, and largely contributed to the interest of our meetings. I think I am justified in saying, that a great advance has been made in the scientific status of the Society during the years referred to. Still it must be remembered that very few of the members contribute to the published volume of "Proceedings," and if their number was reduced, the Society would have to depend on those who

* "Geol. Mag.," Dec. iii., vol. iii., pp. 93-5. † "Nature," vol. xxxiv., p. 200.

have hitherto contributed little or nothing at our meetings. It is therefore most desirable that our younger members should endeavour to give such adequate time to special geological subjects as would enable them to make communications to the Society. With a little careful study they would soon find it possible to do original work, which alone can be of any permanent benefit to the Society.

It is gratifying to record that the President's address at the recent meeting of the British Association at Birmingham was on the Atlantic Ocean, the subject of our ex-president, Mr. T. Mellard Reade's address last year. Since that address was given, several papers have been published in the "Proceedings" of this and other Societies connected with our own area. It is not from any desire to dwell on the progress of my own personal work in North Wales, but now that the details of the Carboniferous Limestone and Cefn-y-Fedw Sandstone of Denbighshire and Flintshire are published in our "Proceedings," I hope that the area will prove an instructive field for those who intend to study our science. The formations described extend about 44 miles from north to south and vary from one to five miles in width, and cover nearly, if not quite, 200 square miles, and the survey has extended over seventeen years. During the spring and summer of this year the results obtained from observations in the north of Flintshire were found to be of such interest that I read a paper on that district at the recent meeting of the British Association, but I have been able to include the whole of the details in the volume of "Proceedings" for the last session.

The Cefn caves on the west of the Vale of Clwyd have often engaged our attention in former years, and

you are all doubtless aware that some other caves, on the eastern side of the Vale, have recently been worked by Dr. Henry Hicks, F.R.S., under the auspices of the Royal Society. They are in a ravine near Tremeirchion, only twenty miles from Liverpool, and are known as the Ffynnon Beuno and Cae Gwyn caves.

It has long been my opinion that the Cefn caves were of pré-glacial age, and that they were filled with clay, stones, and other *débris*, containing the remains of numerous mammalia, before the deposition of the boulder clay, as is evident from a description of the caves given in a paper published in the "Naturalists' Journal," June, 1866, "On the Geology of the Country bordering the Mersey and Dee." The Cefn caves do not seem to have been used as the dens of hyænas and other animals, but however that may have been, they were found choked up with *débris*, containing numerous bones and teeth of mammalia mostly extinct in the British Islands. But in the Tremeirchion caves the conditions are very different, for a bone-earth covers the lower portions, and evidently formed the floor of both of them. In June last, at the invitation of Dr. Hicks, I visited the caves with him, and we found in the Cae Gwyn cave the bones and teeth of the bear, hyæna and reindeer, while a man, working under our direction with a pick, broke off a lump of clay 18 inches below the original floor of the cave and found a flint-flake, which we both recognised at the same instant as the first conclusive specimen of the work of man ever found below the boulder clay. All the details of this important discovery were given in "Nature," for July 8th, 1886, by Dr. Hicks, and they will be published in the next "Report of the British Association." As I have been elected a member of the committee for making further explorations at the Cae

Gwyn cave under a grant from the British Association, I hope to have an opportunity of showing how clearly the cave-earth is pre-glacial to any members of the Society who may be able to visit that interesting locality.

An important paper was read before the Geological Society early this year on "The Glaciation of South Lancashire, Cheshire, and the Welsh Border," by Mr. A. Strahan, M.A., F.G.S. With regard to the striæ in the country around Liverpool, he agrees with my own conclusion, as given in a paper read before this Society in March, 1877, and printed in our "Proceedings"—that the striæ were caused by the varied course of drifting ice having the same general direction. Mr. Strahan's paper is a valuable contribution to our local geology, and it contains references to all that has been written on the subject. Prof. H. Carvill Lewis, however, in a paper read at the last meeting of the British Association, favours the theory of a great ice-sheet invading and covering the country.

An interesting exploration has been conducted during the last three months under the tumulus at the Gop, near Newmarket, but it is more of Archæological than Geological interest, and the time warns me that I must now proceed to the more special subject of my address, which, availing myself of the President's wide field of selection, I have now to bring before you. In these days when the Archæan rocks, and the microscopical examination of all rocks, occupy such a prominent position in Geological investigation, it is difficult to avoid some reference to those subjects. My address, however, is on "Early Life on the Earth; or the first appearance of the classes of Plants and Animals in the Geological formations," a subject so old-fashioned that I shall have little to say on the Archæan rocks.

I am aware of the difficulty of presenting the subject in a satisfactory manner—principally from the impossibility during the last year of reading and digesting the vast amount of detail recently written by many palæontologists on the various branches of the subject. To have attempted to give the details of each order would have expanded my address beyond a reasonable length, and as the time at my disposal is limited, I have so condensed the subject as to render it suitable for the occasion. In selecting so wide a field I have some slight advantages, for it has been my good fortune to visit most of the localities in Great Britain remarkable for affording the earliest traces of the successive plants and animals, and I recall with pleasure days spent at Church Stretton, Bray Head, St. David's, Shelve, Ludlow, Elgin, Stonesfield, and other places that must ever remain classical ground to geologists. Fossil collecting in these localities enables me to illustrate much of my address by the actual species I have to refer to, though enlarged drawings of them would in some respects have been preferable.

In 1858 I read a paper before the Literary and Philosophical Society of Liverpool, on "The Flora and Fauna of Geological Systems," which was published in the "Proceedings" of the Society. It was a record of what was known at the time, and it is an interesting subject of enquiry to ascertain what advance in our knowledge has been made during the last twenty-eight years—but this may be more profitably done towards the end of the address. It will, however, be remembered that the greatest additions to our knowledge are concentrated about the lower formations and the organic remains found in them, and that whatever may be said about the dawn of life upon the earth, the earliest strata seem to

have been deposited under entirely different conditions to any that prevail now, and when life was an impossibility.

The Archæan rocks are the most ancient in the Geological series, and are made up of gneiss, mica schist, and other schistoze rocks, associated with subordinate beds of quartzite, limestone, graphite, and iron ore. It does not seem possible at present to make any classification of the Archæan rocks, though there seems to be an upward tendency to a more stratified condition, and an approximation to strata of later age. The Pebidian seems to be of this transitional period; but still there is a great break in both stratification and in lithological characters between the highest Archæan and the lowest Cambrian strata. There is no instance known of a gradual passage from the lower to the higher series, and the Archæan seems to have been formed under conditions peculiar to the early stages of the earth's history.

The Cambrian usually begins with a conglomerate, but it does not directly succeed the Archæan, for the unconformity between each series is always clear and distinct. The Archæan seems to correspond with the Gneiss and Mica Schist Systems of the early geologists, so after all that has been written on metamorphism we seem to have gone back to the views held fifty years ago.*

The occurrence of limestone, graphite and iron-ore seems to indicate the presence of life long anterior to the Cambrian period, but the deposition of these rocks and minerals was probably the result of chemical operations acting on a vast scale and in a manner we have no conception of, for they occur low down in the

* Page, "Rudiments of Geology," 1st Ed, 1844.

Archæan series, and not towards the end, when there may have been an approach to present conditions. There may have been a beginning of life near the close of the Archæan period, for with nitrogen at hand protoplasm may have been developed, and the earliest forms evolved with the early dawn of oceans and continents.

The only supposed organic body hitherto discovered in the Archæan series is recorded under the name of *Eozoon Canadense*, and has been supposed to be of Foraminiferal type, and allied to the genus *Carpentaria*. You must all be familiar with the long-continued difference of opinion that has prevailed as to the organic or chemical origin of this serpentinized limestone, and which is not even yet concluded; but it seems to me that the most general conclusion is that it is the result of mineral absorption and substitution, and consequently not of organic origin. This is now the opinion of the majority of palæontologists in this country and in North America, so that we cannot accept the *Eozoon* as the lowest and earliest form of life. The occurrence of other fossils in the Archæan rocks has on several occasions been brought forward, but they have all been found on examination not to be the remains of organic bodies.

In describing the earliest known species of plants and animals found in the lowest strata, it must not be supposed that they are actually the first that existed upon the earth. They are, however, the earliest species that have been found, and possess great interest on that account, but probably succeed still earlier forms that came into existence by some process of evolution about the end of the Archæan, or the beginning of the Cambrian period.

I intend to limit my observations as much as possible to the first appearance of each class of the vegetable and animal kingdoms, and especially to those that occur in Britain; but it must be remembered that the earliest fossiliferous rocks occur in this country. It seems that the eastern boundary of the Cambrian Atlantic was formed of Archæan land, which only gradually attained a great elevation several hundred miles from the coast line, and that such a great and long-continued subsidence began in early Cambrian times as allowed an enormous thickness of sediment to accumulate along its margin, and that the deepest and thickest deposits were formed along the south-west of our present European coasts. The result of this subsidence was that the earliest formations were deposited about what are now Great Britain, France, and Spain, and that only the later Cambrian and Silurian deposits were laid down in Norway and the more eastern European area. The consequence was that the early Cambrian strata on the west were overlapped by those of later age; while farther east and north, the lowest Cambrian strata were never deposited; and this is the cause of the British Islands affording such favourable conditions for discovering the earliest traces of life on the earth.

These conclusions are condensed from a paper by Dr. Hicks, F.R.S.,* and may be shewn by the ascending horizon of the base of the Cambrian as it rests on Archæan rocks in different countries, or by a diagram arranged to show the overlap described.

In North America there is a similar early series of the Cambrian rocks, though they do not seem so thick as in this country, and may not reach so far back in

*Hicks, "Quar. Jour. Geol. Soc.," vol. xxxi, p. 552.

time, while the earliest species represent classes in much the same order of occurrence as in Europe.

I may here refer to the difficulty of using such vague terms as Cambrian and Silurian as being misleading, unless the meaning attached to them be given by the author who uses them. To avoid taking up your time by giving my own views on the subject, I shall try to avoid those terms by referring directly to the precise formations into which the Cambrian and Silurian are divided.

Leaving out of consideration the possible occurrence of organic remains in the Archæan rocks, we find in Great Britain several areas (about eight or nine) of the lowest strata, and that the principal districts where these—the Longmynd Rocks—occur, are Church Stretton, Bray Head, and St. David's, each of which has yielded some of the earliest fossils found in this or probably any other country. The first named, the Longmynd series of Church Stretton, is much the thickest deposit, and I shall consequently assume that its lowest portion is much older than the others.

The arrangement of the Vegetable and Animal Kingdoms adopted is similar to that of Prof. J. Morris, F.G.S., in his "List of British Fossils," 1854, and that of Mr. R. Etheridge, F.R.S., in the recent edition of Philips' "Manual of Geology," 1885. The only modifications being the adoption of the Hydrozoa and Actinozoa in conformity with the latter work, and the retention of the Monomyaria and Dimyaria of Prof. Morris, instead of including them under the Pelecypoda of Mr. Etheridge. The Arachnida, Myriapoda, Insecta, and Heteropoda are also separately referred to as for the most part done in the latter work.

In the following Table the Classes are placed in the order of supposed first appearance, and not according to any organic classification. I shall, however, refer to the Classes in the botanical and zoological order of arrangement referred to.

ORDER OF OCCURRENCE OF THE CLASSES OF THE VEGETABLE KINGDOM IN GEOLOGICAL FORMATIONS.

CLASS.	FORMATION.	LOCALITY.
Thallogens	Longmynd	Brayhead
Acrogens	Wenlock	Corwen
Gymnogens	Devonian	Wick
Endogens	Inferior Oolite	Charmouth
Exogens	Eocene	Bournemouth

(Cretaceous, Aix-la-Chapelle, and N. America.)

ORDER OF OCCURRENCE OF THE CLASSES OF THE ANIMAL KINGDOM IN GEOLOGICAL FORMATIONS.

CLASS.	FORMATION.	LOCALITY.
Annelida	Longmynd	Church Stretton
Brachiopoda	,,	St. David's
Crustacea	,,	,,
Amorphozoa	,,	,,
Pteropoda	,,	,,
Echinodermata	Menevian	Ramsey Island
Heteropoda	Middle Lingula flags	
Polyzoa	Upper Lingula flags	Tremadoc
Hydrozoa	Shineton Shales	Shineton
Dimyaria	Lower Tremadoc	St. David's
Cephalopoda	Upper ,,	,,
Gasteropoda	Arenig	,,
Actinozoa	Llandeilo	S. Wales
Monomyaria	,,	,,
Foraminifera	,,	Girvan

CLASS.	FORMATION.	LOCALITY.
Cirripedia	Wenlock	Dudley
Arachnida	Lower Ludlow	Ludlow
Pisces (Ganoidei)	Ludlow	Lesmahago
Myriapoda	Old Red Sandstone	Forfarshire
Insecta	Coal-measures (Lower Llandovery, Normandy.)	Coalbrookdale
Reptilia (Labyrinthodontia	Coal-measures	Northumberland
Mammalia (Marsupial)	Keuper	Watchett
Birds	Wealden (Oolite, Germany, and N. America.)	Brook

THALLOGENS.

The earliest known Thallogens occur in the Longmynd series of Bray Head, and were described by Goppert as *Oldhamia*, of which there are two species, *O. radiata* and *O. antiqua*; they resemble *Corallina officinalis*. The genus has been referred to the Hydrozoa or Polyzoa by E. Forbes and others. Fucoids occur low down in the Longmynd rocks of St. David's, and Dr. Hicks records them in both the Caerfai and Solfa groups. There is often a doubt about fucoids, for they seldom show any very definite form, and are liable to be confounded with annelid tracks, though some show structure and admit of clear description. Dr. Hicks found *Nematophycus Hicksii* in the Denbighshire Grit, near Corwen,* a fucoid previously described as *Prototaxites*, a land plant, from the Devonian of Gaspé, Lower Canada, by Sir Wm. Dawson. Higher in the palæozoic series fucoids are frequent, and occur all through the geological formations.

* Hicks, Quar. Jour. Geol. Soc , vol. xxxvii. p. 482.

The supposed fucoids of the Keuper Sandstone of Storeton, Cheshire, and one figured in Lindley and Hutton's "Fossil Flora" as the leaf of a dicotyledonous plant, are of a dendritic character.

ACROGENS.

The earliest traces of Acrogens were recently found at the base of the Denbighshire Grit at Pen-y-Glog, near Corwen, North Wales, by Dr. Hicks.* They consist of the stems of a plant combining the characters of both *Lepidodendron* and *Sigillaria,* which has been named *Berwynia Carruthersi,* and associated with it were the seeds or spore-cases *Pachytheca sphærica.* These spores have been long known in the highest beds of the Upper Ludlow, where they occur in a remarkably perfect condition, and were referred to the Lycopodiaceæ by Dr. Hooker, but those found at Corwen are smaller and somewhat broken. These remains of plants indicate dry-land conditions during the deposition of the Denbighshire Grit, but no other species have been found excepting fucoids. In the Upper Ludlow there are some indications of land plants, and in France and Ohio they have been recorded from a rather lower horizon. In the Devonian the Acrogens are well represented, and at Kiltorcan, Kilkenny, luxurious fronds of *Adiantites Hibernicus* occur, associated with *Anodontia Jukesii,* a freshwater bivalve mollusk resembling our recent *Anodon* or *Unio*, in the Yellow Sandstone at the top of the Devonian.

GYMNOGENS.

The earliest remains of Gymnogens occur in the Devonian, and are represented by *Araurocaryoxylon* from Ireland, and *Pinnularia* and coniferous wood from

* Hicks, Quar. Jour. Geol. Soc., vol. xxxviii., p. 97.

Wick. The vegetation of the Devonian closely resembled that of the Coal-measures, but the specific forms were different. In North America the vegetation seems to have been much more prolific than in Europe, though the Devonian there may be homotaxeous and not contemporaneous with the formation in Britain.

In the Carboniferous the Gymnogens must have been very numerous, though the number of genera and species described is few. Their abundance, however, is proved by the frequent occurrence of the woody tissue containing discs with concentric lines of growth so well known to microscopists. The *Cardiocarpon* and *Trigonocarpon,* formerly supposed to belong to the Palmacæ are now considered to be the fruit of a Conifer, and probably Dr. Dawson is correct in his opinion that they belong to Sigillarioid plants. Trees of the Sigillarian type are now regarded as Gymnospermous Exogens. Considering the numerical importance of the Conifera in time, it is remarkable that so few cones have been found in the Geological formations.

ENDOGENS.

Although there is some evidence of the existence of Endogens as early as the Trias, the earliest undoubted species is probably *Podacarya Bucklandi,* from the Inferior Oolite of Charmouth, and it belongs to the Pandanæ. There are other genera and species from higher Oolitic formations, though they are by no means numerous, and some very doubtful. Endogenous wood has, however, been discovered in the Carboniferous and Permian. Endogens have been recorded from the Coal-measures, including *Pothocites,* which is now known to be part of a Sigillarian tree.* The others seem to be

* Gardner, "Geol. Mag.," Dec. iii., vol. iii., pp. 193 and 382.

very doubtful, and even the genera referred to the Palms are no longer entertained, and no trace of them recorded from Mesozoic strata. In the Upper Cretaceous and Eocene the Endogens become abundant, and according to Mr. T. S. Gardner, F.G.S., the Gramineæ are only traced from the Upper Eocene with any certainty. There is evidently some connection between the advent of the Grasses and the appearance of whole tribes of graminivorous mammalia towards the close of the Eocene period*

EXOGENS.

The earliest Angiospermous Exogens in Britain occur in the Eocene, and approximate in genera to those now existing. The Cretaceous strata of North America, Aix-la-Chapelle, and Greenland have yielded a large number of genera and species. In Greenland Prof. Heer has described nearly 200 species of Exogens, including such forms as aralia, buckthorn, cassia, cinnamon, dogwood, eucalyptus, fig, ilex, ivy, laurel, magnolia, myrica, oak, plane, poplar, sassafras, and walnut. There is, however, no certainty that these foreign Cretaceous beds were contemporaneous even with the Chalk of this country, and it is very possible that they may be of somewhat later age, tending to fill up the immense gap in the geological record that exists between the Chalk and the lowest Eocene strata in Britain. In the Middle Bagshot Sands at Bournemouth are remains of the laburnum, poplar, and willow, and the variety of the vegetation is remarkable. There are dictyledonous leaves, flowers and fruit, besides remains of Palms, Conifers, and Ferns.†

* Gardner, "Proc. Geol. Assoc.," vol. ix., p. 433.

† Gardner, "British Eocene Flora," vol. i., pp. 7 and 17.

From the first occurrence of each class of the vegetable kingdom in the geological formations, it appears that the Gymnogens came into existence long before the Endogens, and, with that exception, the succession does not differ from the usual progressive arrangement of plants. The Gymnogens have generally been placed next to the Exogens by botanists, between the two classes forming the Phanerogamic plants. The far greater antiquity of the Gymnogens indicates that evolution proceeded from the Acrogens through the Gymnogens, and that the Endogens and Exogens were the last to appear. Recently Sachs and others have come to the conclusion that the Gymnogens form the intermediate class between the Aerogens and the two classes of flowering plants.

AMORPHOZOA.

The earliest Amorphozoa are represented by the genus *Protospongia*, one of the Hexactinellidæ, of which two species occur in the middle of the Longmynd series at St. David's—*Protospongia fenestrata* and *P. major*. They occur as spicules converted into iron pyrites, and are associated with a few other fossils. These two species and two others occur in the overlying Menevian, and there are a few species in most of the lower Palæozoic formations. *Hyalostelia fasciculas* ranges from the Tremadoc to the Denbighshire Grit, and occurs in the Llandeilo, at Llandeilo and Shelve.

FORAMINIFERA.

The earliest species of Foraminifera recorded is *Saccammina Carteri*, from the Craighead Limestone, Girvan,* which according to Prof. Lapworth is on the

*Nicholson & Etheridge, "Mono. Sil. Fos., Girvan," Pt. i., p. 21.

horizon of the Llandeilo formation. In the Lower Llandovery of Cwm Symlog, Cardiganshire, *Dentalina communis*, *Textularia sp.*, and *Rotalia sp.* have been found by the Rev. J. F. Blake and Mr. Walter Keeping, F.G.S.* In the Wenlock Limestone shales from Lincoln Hill, Ironbridge, Dormington, Woolhope, and Benthall Edge, *Lagena vulgaris* and the varieties *lævis*, *clavata*, and *sulcata* have been found, on the authority of Prof. Rupert Jones, F.R.S.† The near affinity of these early to recent species is remarkable. Mr. G. R. Vine informed me that during the recent washing of Wenlock Shale, some thousands of minute specks passed under his glass without any Foraminifera being found; so that they seem to be scarce and very local. Mr. W. Pengelly, F.G.S., informed me that he had never found Foraminifera in the Devonian rocks of Devon and Cornwall. *Saccammina Carteri* occurs in the Lower and Upper Bernician of Northumberland, and in the Carboniferous Limestone at Minera, near Ruabon. Foraminifera are numerous in the same formation of Denbighshire and Flintshire, and most polished sections show one or more species.

HYDROZOA.

The earliest Hydrozoa occur in the Shineton Shales, where two species, *Clonograptus*, sp. and *Bryograptus*, *Callavei*, have been found. In the Lower and Upper Tremadoc none have been discovered, so that those in the Shineton Shales are the oldest Rhabdophora known.‡ In the overlying Arenig the Hydrozoa are abundant, many genera and species having been recorded.

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*Jones, "Geol. Mag.," Dec. ii., vol. ix., 1882, p. 490, and Dec. ii., vol. iii., 1876, p. 134.

† Jones, "Geol. Mag.," Dec. ii., vol. viii., 1881, p. 70.

‡ Etheridge, "Manual of Geol.," vol. ii., p. 54.

ACTINOZOA.

The earliest Actinozoa are *Halysites catenulatus*, *Favosites fibrosus*, and *Monticulopora favulosa* and occur in the Llandeilo of South Wales. They are the first corals that occur, they all three pass upwards into the Caradoc, and the two first into the Wenlock, where the Actinozoa are abundant in genera and species.*

ECHINODERMATA.

The earliest Echinoderm is a Cystidean—*Protocystites Menevensis*, and occurs in the Menevian. No Echinoderm is again found until *Dendrocrinus Cambrensis*—a crinoid, and *Palæasterina Ramseyensis*—an asteroid, appear in the Lower Tremadoc of Ramsey Island.† Other species of Crinoidea and Asteroidea are found in the Llandeilo, including *Glyptocrinus basalis*, found at Mincop, Shelve.

The Blastoidea first occur in the Upper Silurian of N. America and the Devonian of Britain, the Ophiuroidea in the Lower Ludlow at Leintwardine, and the Echinoidea in the Upper Llandovery formation.

ANNELIDA.

The burrows and tracks of Errant Annelids occur in the lowest beds of the Longmynd formation at Church Stretton, St. David's, and Bray Head. The lower beds of the former are probably the lowest Cambrian in Great Britain, and present tracks of Annelids, so that it might be inferred that they were the first animals that existed, though such a conclusion would be very doubtful. These Annelids, *Arenicola didyma*, are found near Church Stretton, associated with rain-drops, sun-cracks, and ripple-surfaces. *Arenicolites Uricomiensis* occurs in the

* Etheridge, "Manual of Geol.," vol. ii., p. 72.

† Hicks, "Quar. Jour. Geol. Soc.," vol. xxix., p. 39.

quartzite of the Wrekin, and if that formation belongs to a still earlier period, it would be the oldest fossil found in Great Britain.

Histioderma Hibernica, Arenicolites didymus, A. sparsus, and *Haughtonia pœcila* occur in the Bray Head group, associated with what Dr. Kinahan supposes to be Molluscan tracks. *Chondrites* occurs in the Bangor group. Annelid tracks occur in the Caerfai and Solfa groups, forming the Longmynd series of St. David's.

In the overlying Menevian, *Arenicolites didymus, A. sparsus,* and *Serpulites fistula* are found, the latter being the first recorded Tubicolous Annelid that possessed a horny or shelly covering. Above the Menevian, Annelids are common in all the Geological formations.

CIRRIPEDIA.

The earliest known Cirripede is *Turrilepas Wrightianus,* found in the Wenlock, at Dudley, and in the Ludlow formation in the Pentland Hills. It is a Pedunculate genus of the Lepadiæ, and is the only Cirripede in the Lower Palæozoic formations. The class is also represented in Bohemia and North America. In the Oolite there are three species, and many in the Cretaceous when the Lepadiæ seem to have reached their culminent point.

The Sessile Cirripedia, comprising the Balanidæ and Verrucidæ, occur for the first time in the Lower Greensand, which contains two genera, *Pollicipes* and *Scalpellum,* there being one species of each. Other genera and species are found in the higher Cretaceous formations, and there are others in the Eocene and the Coralline, and Red Crags.

CRUSTACEA.

The earliest Crustacea are found in the Longmynd group of St. David's. The lowest species recorded is *Leperditia Cambrensis,* an Entomostracan found associated with two species of *Lingula.* The following Trilobites:—*Microdiscus sculptus, Conocoryphe Lyellii, Paradoxides Harknessi, Plutonia Sedgwickii* and *Agnostus Cambrensis* occur in a higher zone. *Conocoryphe Solvensis, Paradoxides Harknessi, Agnostus Cambrensis* still higher; and *Conocoryphe bufo, Paradoxides aurora,* and *Agnostus Cambrensis* in the highest zone of the same formation.* The Crustacea seem to appear just after the Brachiopoda, but there is so little difference that they almost come in together, and the Trilobites are the first to appear abundantly in both species and individuals, including both large and small species, some of which occur again in the overlying Menevian. Some of the genera:—*Agnostus, Microdiscus* and *Erinnys* are destitute of the facial suture, and seem to have had no eyes. The Trilobita became extinct with the Coal-measures. The earliest Phyllopod is *Hymenocaris vermicauda* in the Lower Lingula flags, and *Caryocaris Wrightii* is a common fossil in the Skiddaw Slate. The Phyllopoda, Trilobita, Merostomata and Amphipoda occur in the Ludlow formation, while the Isopoda first appear in the Devonian and the Stromapoda in the Coal-measures. Of the Decapod Crustaceans; the Macrura appears in the Carboniferous; the Anomura and the Brachyura for the first time in the Oolite.

ARACHNIDA.

The earliest species of Arachnida is a Scorpion discovered by Dr. Hunter in the Ludlow formation of

* Hicks, "Quar. Jour. Geol. Soc.," vol. xxvii., p. 396.

Lesmahago, Lanarkshire, in 1884.* In the same year another Scorpion was found in the Upper Silurian of Gottland, Sweden, and named *Paleophoneus nuncius* by Dr. Lindström.† It is remarkable that another species was discovered in 1885 in the Waterlime group, Lower Helderberg of Oneida County, N.Y. Four species are recorded from the Coal-measures of Lancashire, Staffordshire, Coalbrookdale, and Dudley. Dr. Buckland figured a Scorpion in the "Bridgewater Treatise" in 1836, from the Coal formation of Bohemia, with a Spider and an Insect from Coalbrookdale.

MYRIAPODA.

The earliest Myriapods known in great Britain occur in the Old Red Sandstone of Forfarshire, and in ironstone nodules in the Coal-measures at Coalbrookdale, Dudley and other localities. In North America and Bohemia they have also been found in the Coal-measures.‡

INSECTA.

The earliest Insect recorded was found last year in the Jurques Sandstone, on the horizon of the Upper Llandovery, at Calvados, in Normandy. It has been named *Palæoblattina Douvillei,* and placed with the Blattidæ, a family of the Orthoptera.§ This order and the Neuroptera occur in the Devonian rocks of New Brunswick, but not in those of Great Britain. Orthoptera, Neuroptera, and perhaps Coleoptera in the Coal-measures, but there is some doubt as to the latter. *Curculionides Ansticii* from the Coal-measures of Coal-

* Goss, "Proc. Geol. Assoc.," vol. ix., p. 144.
† Brongniart, "Geol. Mag.," Dec. iii., vol. ii., p. 484.
‡ Woodward, "Geol. Mag.," Dec. iii., vol. iv., p. 1.
§ Goss, "Proc. Geol. Assoc.," vol. ix., p. 143.

brookdale, was described by Dr. Buckland and may belong to the Coleoptera.* Recently a large number of Insects have been obtained from the Carboniferous strata of Commentary, Allier, France. In addition to Orthoptera and Neuroptera, Hemiptera have been found at Commentary, and in North America, but they are very rare.

Two wings of an Orthopterous Insect, Protophasmidæ, from the Ravenhead beds, Middle Coal-measures, are in the Liverpool Free Public Museum.

POLYZOA.

The earliest known Polyzoon is *Dictyonema sociale*, found in the Upper Lingula flags, and in the Lower Tremadoc, in both North and South Wales, and at St. David's.† It occurs at Malvern, and at Merivale, Nuneaton, in strata, until recently considered to be Coal-measures. It also occurs in the Shineton Shales. The Polyzoa are represented in the Coniston Limestone by *Fenestella assimilis* and *Ptilodictya,* and in the Lower Llandovery by other species of those genera. In the Wenlock and Ludlow formations they are well represented, though not very numerous.

BRACHIOPODA.

The earliest Brachiopoda occur in the Longmynd rocks of St. David's, where *Lingulella ferruginea, L. primeva, Discina pileolus,* and *D. Caerfaiensis* are found with some of the lowest fossils known, including *Leperditia Cambrensis,* but the Brachiopoda are the lowest. In the Menevian, *Lingulella ferruginea* again occurs with *Discina pileolus, Obolella sagittalis, O. maculata,* and

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* Woodward, "Geol. Mag.," vol. viii, p. 385.

† Etheridge, "Manual of Geol.," vol. ii., p. 50.

Orthis Hicksii,* the latter being found only in the upper beds. Other genera succeed in the Tremadoc and Arenig formations, and are abundant in the later Palæozoic and the Mesozoic strata.

MONOMYARIA.

The earliest Monomyaria occur in the Llandeilo, and are represented by *Pterinea megaloba*, and in the Caradoc by several species of the same genus and of *Ambonychia*. They are well represented in the Upper and Lower Llandovery, Wenlock, and Ludlow formations.

The Monomyaria are not of equal numerical importance with the Dimyarian Mollusca, though of great geological value, as the genera are easily recognised.

DIMYARIA.

The earliest Dimyaria occur in the Lower Tremadoc rocks of Ramsey Island, which affords the first evidence of bivalve mollusca in Britain. There are the following genera, containing 12 species—*Ctenodonta*, *Davidia*, *Glyptarca*, *Modiolopsis*, and *Palæarca*.† It does not appear that any particular species occurs at a lower horizon than the others, but not one of them has been found in the succeeding formations. In the Arenig of Shelve there are four genera containing the same number of species. The largest is *Modiolopsis trapeziformis*, which I named myself, and the others are *Palæarca amygdalus*, *Redonia Anglica*, and *Ribieria complanata*. The Dimyaria are more important and numerous in the Caradoc, there being fewer in the Wenlock and Ludlow formations.

* Hicks, "Quar. Jour. Geol. Soc.," vol. xxvii., p. 396.
† Hicks, "Quar. Jour. Geol. Soc.," vol. xxix., p. 39.

PTEROPODA.

The earliest Pteropoda occur in the Longmynd series at St. David's, *Theca antiqua* and *T. penultima* occurring in the middle and upper beds. The latter species is found in the overlying Menevian, and other species in the Lower Tremadoc. *Conularia* and *Theca* occur in the Upper Tremadoc and Arenig. *Theca simplex* is the common Arenig species at Shelve. There are several species of *Theca* in the Llandeilo of St. David's, but none in the same formation at Builth, Llandeilo, or Shelve. The largest known Pteropod fauna is in the Caradoc. There are also a few species in the Lower and Upper Llandovery, Wenlock, and Ludlow formations.

HETEROPODA.

The earliest known Heteropod is *Bellerophon Cambrensis* in the Middle Lingula flags, and then there are *Bellerophon Shinetonensis* from the Shineton Shales, *B. Ramseyensis* and *B. Solvensis* from the Lower Tremadoc, *B. arfonensis* and *B. multistriatus* from the Upper Tremadoc. Three other species, *B. carinareoides*, *B. perturbatus*, and *B. hippopus*, occur in the Arenig of the Shelve district. *Bellerophon multistriatus* and *B. Llanvernensis* occur in the Arenig of S. Wales. The Heteropoda are most numerous in the Lower Silurian or Upper Cambrian formations.

GASTEROPODA.

The earliest Gasteropoda are *Pleurotomaria Llanvernensis*, and *Ophileta* sp. in the Arenig of Llanvern, St. David's. *Rhaphistoma* sp. occurs in the same formation at Shelve and Skiddaw. *Cyclonema crebristria* and *Euomphalus Corndensis* occur in the Llandeilo at Shelve. The Gasteropoda become numerous in the Bala and Caradoc formations.

Terrestrial Gasteropods of the genera *Dawsonella*, *Helix*, and *Pupa* have been discovered in the Coal-measures of Nova Scotia, but have not been found again below the Eocene formation.

CEPHALOPODA.

The earliest Cephalopoda known in Britain are *Cyrtocerus præcox* and *Orthoceras sericeum* in the Upper Tremadoc, and the latter passes upwards into the Arenig. An *Orthoceras* from a rather earlier formation was, however, found by Dr. Hicks in the Lower Tremadoc at Solva, St. David's. The next species in ascending order are in the Arenig of Shelve, where *Orthoceras Avelinii* and *O. encrinale* occur. There are no Cephalopoda in the Skiddaw Slate, but *Orthoceras sericeum* and *O. Caereesiense* are found on the same horizon at St. David's. In the Llandeilo at Builth I found an *Orthoceras*, the species of which is undetermined. There is a South Wales species, and some from Scotland—including *Pilòceras invaginatum* from the Durness Limestone. In 1884 I saw a bed of *Orthoceras vagans* in the Coniston Limestone on the top of Skilgill. The specimens were about two feet in length, and as *O. vagans* is the only species recorded, I concluded it to be that species. In the Bala and Caradoc the Cephalopoda become more numerous, and occur in all succeeding formations.

PISCES.

The earliest known Fishes have been found in the Lower Ludlow, and *Scaphaspis Ludense* is the first that appears. Cephalic shields and other portions were found about 20 years ago by Mr. A. Marston, of Ludlow, and some of them are in my collection. In the Upper Ludlow they are more frequent, and fragments of other fishes occur in the bone-bed, at the top of the formation.

In the overlying passage beds *Auchenaspis Egertoni*, *A. Salteri*, and *Cephalaspis ornatus* occur. The Upper Ludlow passes upwards into the Old Red Sandstone where fishes are abundant, and fine specimens of the cephalic shields of *Cephalaspis Lyellii*, *Scaphaspis Lyellii*, and *Pteraspis rostratus* of frequent occurrence. A tolerably perfect specimen of *C. Lyellii*, from Ludlow, is in my collection, and it is figured in the "Geologist," vol. iv., p. 141, and in Prof. E. Ray Lankester's Monograph of "The Fishes of the Old Red Sandstone of Britain," p. 43, Plate viii. All the fishes referred to belong to the Ganoidei, but the Placoidei and Dipnoi, also occur in the Old Red Sandstone. The Teleostean, or Bony fishes, appear for the first time in the Cretaceous period.

AMPHIBIA.

The earliest Amphibia occur in the Coal-measures, and belong to the Labyrinthodontia, of which there are many genera and species in that formation in Britain, the Continent of Europe, and N. America. Their remains include the skulls which are found in a very perfect condition, but they are mostly in private collections, though that of the late Mr. T. Atthey, F.G.S., consisting of Fishes and Amphibia, is now in the Museum of the Natural History Society of Northumberland, at Newcastle-on-Tyne. *Loxomma Allmani*,* *Batrachiderpeton lineatum* and *Pteroplax corunta* are examples of many species described by Prof. L. C. Miall in the "Reports on the Structure and Classification of the Labyrinthodonts of the Coal-measures.† The length of the skulls of these three species, as given by Prof.

* A plaster cast of a very perfect skull of this species is in the Free Public Museum, Liverpool. The original was found near Coalbrookdale, and is now in the British Museum.

† "Reports Brit. Assoc.," vol. for 1873, p. 225, and vol. for 1874, p. 149.

Miall, is 13, 2, and 7 inches respectively. These Amphibia were most nearly allied to the Urodela, and probably resembled our recent freshwater Tritons, though much larger. The Labyrinthodont character of the *Cheirotherium* footprints at Storeton seems to be doubtful, for Prof. Miall states that "there is not a single distinctive Labyrinthodont feature about *Cheirotherium*," and that it may be Dinosaurian. The largest known Labyrinthodont is *Mastodonsaurus giganteus* from the Keuper, Rhætic, and Muschelkalk, and a specimen of the skull from the latter formation in the Museum at Stuttgard measures 30 inches in length. The Amphibia were most numerous from the Carboniferous to the Trias, after which they declined in importance.

REPTILIA.

The earliest reptiles known in Britain belong to the Lacertilia, and occur in the Permian. There are two species, *Protorosaurus speneri* and *P. Huxleyi* from Durham and from the same horizon in Germany. The Dinosauria are represented in the Trias at Bristol by *Thecodontosaurus* and *Palæosaurus*. The Triassic Sandstone of Elgin, Morayshire, is famous for its reptilian remains, where the Crocodilia are represented by *Stagonolepis Robertsoni*, the Lacertilia by *Telerpeton Elginense, Hyperodapedon* and *Rhynchosaurus*, the Anomodontia by *Dicynodon*, and the Dinosauria by undescribed relics, so that no less than four orders of reptiles occur at Elgin.* The Ichthyopterygia is represented by *Ichthyosaurus*, the Sauropterygia by the *Plesiosaurus*, and the Pterosauria by the *Pterodactylus* and other genera, all first appearing in the Lias, and disappearing in the Cretaceous. The earliest Chelonia occur in the Oolite, but supposed

* "Report Brit. Assoc.," vol. for 1885, pp. 1023-4.

footprints, *Chelichnus Duncani*, in the Permian at Annandale, Dumfriesshire, have been referred to them. No remains of the Ophidia are known below the London clay of the Isle of Sheppy, *Palæophis toliapious* being the oldest known serpent.

AVES.

The earliest traces of Birds occur in the Wealden. In the Upper Greensand, two species of *Enaliorus* have been found, but in the Eocene several species have been recorded, and the occurrence of most of the orders of existing birds in more recent deposits proves that there was nothing to prevent their remains being preserved in earlier formations if they had existed. The supposed birds indicated by large footprints in the Trias of N. America, and bones from Stonesfield are no longer entertained, for the former are now considered to be Dinosaurian, and the latter Pterosaurian remains.

In the Solenhofen Slate, on the horizon of the Upper Oolite, in the centre of the German Jura, the remains of a bird, *Archæopteryx macrura*, have been found. It possesses reptilian characters, teeth, and lizard-like tail.

In the Oolitic rocks of N. America the skull of a bird has been found and described as *Laopteryx* by Professor Marsh, who has also described several genera and species from the Middle and Upper Cretaceous, but it does not appear that they occur in earlier formations than in Europe, though they are far more numerous.

MAMMALIA.

The remains of the earliest Mammal is a tooth of *Hypsiprimnopsis*, or *Microlestes*, found by Prof. Boyd Dawkins in the Keuper Marl near Watchett. The late

Mr. C. Moore, F.G.S., of Bath, found many teeth of *Microlestes antiquus* and other species in Rhætic deposits that occur in fissures in the Carboniferous Limestone near Frome. Similar traces of mammalia have been found at Wurtemburg, N. America, and S. Africa, all apparently on the same or about the same horizon.

In the Stonesfield Slate four genera containing six species have been found, viz.—*Amphilestes*, *Amphitherium*, *Phascolotherium*, and *Stereognathus*, all marsupial except perhaps the last, about which there is some doubt, for it may be placental. The remains are mostly lower jaws, with the teeth attached. In 1854 I was so fortunate as to find the right ramus of the lower jaw of *Phascolotherium Bucklandi* at Stonesfield, and it is in my collection. In the Purbeck beds of Dorsetshire no less than 12 genera, including 28 species of mammalian remains, have been found, and the whole of these are marsupial. No other mammalian remains have been found below the Eocene, when higher orders appear for the first time. The Cetacea and Ungulata appear in the Eocene, but the species were of a more generalised type than those now existing. In the succeeding Miocene most of our present orders were introduced, while in the Pliocene there was a near approximation to our recent mammalian fauna. The Bovidæ are first known in the Upper Miocene of India, but the Ovidæ are only known in Post-Pliocene deposits.

The earliest evidence of the Quadrumana occurs in the Eocene, where there are several Lemuroids. Fossil remains of Platyrhines occur in S. America, and of Catarhine, or old world monkeys, in the Miocene of France and Italy.*

Nicholson, "Manual of Palæontology," vol. ii., p. 419.

Man certainly appeared in the Post-Pliocene, and possibly in the Pliocene, and co-existed with many large mammalian species now extinct.

CONCLUSION.

Naturalists formerly arranged the Vegetable and Animal Kingdoms on a lineal plan and more recently by means of parallel or radiating lines. Quite recently Dr. W. A. Herdman, Prof. Nat. Hist., University College, has prepared a diagram showing the classification of the Animal Kingdom by means of a Phylogenetic Table in a dendritic form. From a central vertical trunk springing from the Protamœba it shows the process of evolution and the successive development of the Infusoria, Radiolaria, Porifera, Cœlenterata, Platyelmia, Echinodermata, Mollusca, Crustacea, Tracheata, and a crowning branch representing the Mammalia. All these Classes or Groups spring separately like branches from the main trunk, and show the relation of one group to another as they grow off from the most simple forms, with a gradual advance in structure from the lowest to the highest types.

One of the most important conclusions drawn from the fossils found in the stratified series is the *general progression* from simple to higher types, from the earliest to the latest geological formations; and it is most important to ascertain how far the first appearance of each class coincides with the theory of evolution, so clearly represented by the Phylogenetic Table.

The Palæontological Table shows the order in which each class occurs for the first time, and the lowest or earliest formation in which it has been found. This order, however, does not seem to present the succession

in which the animals of each class were introduced on the earth; for there is no satisfactory beginning of the invertebrata, no probable root to the Palæontological Tree, and although there is a general advance in the Types of Life, many of the classes do not first appear where we might reasonably expect them. It would have been highly satisfactory if the history of fossils had presented a *regular* advance from low to higher types in each geological formation, with the first evidences of the lowest classes in the earliest and lowest rocks; but although we must not expect an entire correlation between the first appearance of each class and the geological age of the formation in which it occurs, we might reasonably expect a more probable succession of the classes than that I have brought before you.

Although the table showing the successive occurrence of each class of the animal kingdom, gives in a concentrated form the substance of what has been brought forward, it does not seem satisfactory from a biological point of view, except as a record of our knowledge to the present time. "The imperfection of the Geological Record" is an expression that has been often used, and I can only attribute to it, the apparent irregularity and want of continuity in the Succession of Life indicated by the fossils found in the Geological formations. I have already referred to the impossibility of considering on this occasion the orders of which each class is composed, but though they present many evidences of evolution, there is a frequent absence of that regular ascending gradation, which we can only account for by supposing that much still remains to be done in order to complete the broken chain of progression that connects the past ages of the earth's history. On the other hand we must not accept the biological arrange-

ment as a perfect scheme of classification, for it may be hereafter modified and meet some of the Geological difficulties, and Dr. Herdman, in the introduction to the description of his Phylogenetic Table, says:—"No one can be more profoundly impressed than I am with the temporary nature of such a table as this. The rapid advance of biological investigation will probably very soon necessitate additions and corrections to any such phylogenetic scheme."

A comparison between the present Geological Table, showing the first occurrence of the classes, with that published in 1858, shows many additions and corrections, and no doubt another generation will make still further modifications.

It seems probable that with many classes of the Invertebrata we have obtained a near approach to a beginning, and if the advent of some of the others could be found lower down, the whole might be so altered in relative position as to agree with the Zoological succession. It seems almost certain that some of the classes will ultimately be found represented at lower horizons—carried back with the progress of patient search in the early Cambrian formations.

With regard to the Vertebrata we seem to have discovered some of the earliest traces, and although we may find still earlier evidence of their existence, there is not much probability of the first Fishes, Reptiles, Birds and Mammalia being found at a much lower horizon than at present.

In conclusion, I may remind you that the lowest rocks in Great Britain—the rocks most likely to yield traces of the earliest animals that lived on our earth—lie within 60 miles from this city. Before the Archæan

rocks were known the Longmynds of Shropshire were described as the oldest land in England, and the Annelid tracks they contain are still the oldest fossils. It is extremely probable that a thorough search over the Longmynd area, where the strata are about 25,000 feet in thickness, and so well exposed, will yet yield most important Palæontological results.

Some of us, the older Members of the Society, are beginning to feel that it is more difficult than it once was to ramble day after day over those glorious old Cambrian Hills, and the new generation find it difficult to leave the ever increasing busy life of our city; but I hope that some of you may be fortunate and find time to enjoy the breezy air, the beauty of the rounded hills, the grandeur of the deep rocky ravines, and even find fossils low—very low—down in the hard slaty rocks of the Longmynds.

ON THE OCCURRENCE OF INTERNAL CALCAREOUS SPICULES IN POLYZOA.

By J. Lomas, A.N.S.S.

It was while examining the material dredged by the Liverpool Marine Biology Committee, in their last year's expeditions, that the first specimen of *Alcyonidium gelatinosum* containing internal spicules came under my notice.

In order to get a better idea of the arrangement of the zooids in the gelatinous mass which surrounds them, I made transverse sections of the animal for microscopic investigation. Scattered about in the gelatinous mass were small curved, cylindrical bodies, which refracted the light differently from the ordinary soft tissues of the animal.

On treatment with a weak solution of hydrochloric acid they gradually disappear with evolution of gas, thus showing them to be calcareous in their nature. On treatment with weak potash solution the animal matter is rendered transparent, and the spicules are more easily seen. The spicules are more plentiful in the peripheral parts of the colony, and more abundant in colonies of older growth than in young ones. It is easy to see that in large specimens the gelatinous matter would not be able to hold the mass together if hard parts were not introduced to give rigidity and strength to the structure. We see the same thing happening in *Alcyonium*, in many Sponges, and in Ascidians.

The spicules are not the result of post-mortem changes, for I afterwards saw them in living specimens;

nor do I think they are sponge spicules, or foreign matter taken in as food, or enclosed by the sarcode, on account of their position and nature.

They are small in size, the largest not being more than ·14 or ·2 mm. in length (about $\frac{1}{120}$ in.), and in width ·05 mm. ($\frac{1}{300}$ in.)

In shape they are curved slightly, and rudely cylindrical. The surface is pitted and somewhat irregular as a rule, and some have the appearance of being hollow.

No mention is made of these spicules in any work I have had the opportunity of examining, and after corresponding with Mr. Hincks, F.R.S., and others, I am convinced that they are described now for the first time.

I am firmly of opinion that if any of these spicules had been found in a fossil condition they would have been described as sponges, and it is very probable that as our knowledge increases some of the forms now considered to belong to that group will be found to have closer affinities to other orders. There is one special form found by Dr. Hinde in the famous Horstead flint which bears a striking resemblance to the one now under consideration, and is called by him *Reniera Carteri* (*vide* "Fossil Sponge Spicules from the Upper Chalk," by Dr. Hinde, p. 23, and plate 1, figs. 16 and 17, and British Museum Catalogue of Fossil Sponges, p. 19, plate 1, fig. 8). He describes them as cylindrical in form, curved, uniform in calibre, and rounded at both ends. Canals obliterated. There are two varieties, one 0·517 mm. × 0·056 mm., and the other, 0·33 mm. × 0·112 mm. The latter is almost identical in size and shape with the spicules of *Alcyonidium gelatinosum*, and as he had only the external form to judge the characters by, it is possible that he may be mistaken in including them

among the sponges. I do not mean to say that the forms *are* identical, but the analogy is so striking in almost every feature that it serves to throw doubt on his determinations.

Among the materials found in the Pliocene beds of St. Erth, Cornwall, described by Messrs. Kendall and Bell (Q. J. G. S., May, 1886), I have seen spicules which, as regards size and general appearance, are quite indistinguishable from those of *A. gelatinosum*.

THE CARBONIFEROUS LIMESTONE FISHES OF NORTH WALES.

By G. H. Morton, F.G.S.

The frequent occurrence of the remains of Fishes in the Carboniferous Limestone of Bristol, Shropshire, Yorkshire, Scotland, and Ireland, is well known to Palæontologists, and many have been recently described in the "Fossil Fishes of the Carboniferous Limestone Series of Great Britain," by Mr. J. W. Davies, F.G.S.; a work recently printed in the "Transactions of the Royal Dublin Society," 1883. The Author gives a list of the species from various localities in Great Britain, but makes no allusion to any found in North Wales; and I am not aware that any species have been recorded in any work or paper on the Geology of that portion of the country.

During the last forty years I have discovered but few traces of Fishes in the Carboniferous Limestone of North Wales, which is remarkable considering that the formation has frequently been carefully searched for

fossils of every description. The fact of not actually looking for fish remains may, to some extent, account for so few having been found—though I do not think that could have made much difference. The fragmentary teeth that I have found are so broken and imperfect that it has been very difficult, and in some cases impossible, to determine the genera or species, although they have been examined by Mr. W. Davies, F.G.S., of the Natural History British Museum, South Kensington; and the following is the List, which shows that it is very unlikely that N. Wales will ever yield many species. It is impossible that more perfect specimens could have escaped my attention, and those exhibited are sufficient proof of the minute search that has been made.

List of the Carboniferous Limestone Fishes of North Wales.

1. *Cladodus* (tooth) .... Upper Black, Telia, near Gwaenysgor, Prestatyn.
2. *Cladodus mirabilis*, Agass. (tooth), Sandy Limestone, Bryn-gwyn, Mold.
3. *Cladodus mirabilis*, Agass. (numerous teeth and fragments) .... Upper Grey, Coed-yr-Esgob, Prestatyn.*
4. *Petalodus Hastingsia?* Owen (fragment of tooth) .... Upper Black, Pentre Halkin, Holywell.
5. *Petalodus Hastingsia?* Owen (fragment of tooth) .... Upper Grey, Llangollen.

* Found in a bed of hard shale, and might have belonged to a single fish, but the bed is now covered by *débris* so that it cannot be examined at present.

6. *Psephodus magnus?* Agass. (tooth), Upper Grey, Hafod, Corwen.*
7. *Psephodus magnus?* Agass. (fragment of tooth)...................... Upper Grey, Llangollen.
8. *Psephodus magnus?* Agass. (two teeth)................................... Upper White, Pant, Llanymynech.
9. *Psephodus*, sp. (one tooth), Upper Grey, Mold.
10. *Psamodus?* (fragment of tooth), Upper Black, Pentre Halkin, Holywell.
11. *Steblodus oblongus*, Agass. (tooth), Upper Black, Pentre Halkin, Holywell.
12. *Scale* or *Plate?* .... Upper Grey, Llangollen.

In addition to these there were doubtful fragments found in the Upper White, Llanymynech Hill, and in the Sandy Limestone at Bryn-gwyn, Mold, which were thrown out as useless, even for reference. Those in the lists may be tabulated as follows:—

Cladodus *Petalodus* *Psamodus* *Steblodus*	4 genera, containing 4 or 5 species in the Upper Black Limestone and its equivalents.
Cladodus *Petalodus* *Psephodus*	3 genera, containing 3 or 4 species in the Upper Grey Limestone.
Psephodus.	1 genus, containing 1 or 2 species in the Upper White Limestone.

* Dr. Ricketts, F.G.S., found this species in the "Upper Black," or the "Upper Grey," Carboniferous Limestone, near Holywell.

SOME INSTANCES OF HORIZONTALLY SLICKEN-SIDED JOINTS.

By H. C. Beasley.

[*Abstract.*]

The following were described: In the Quarry, near the windmill, at Wallasey, four parallel joints running East and West, and a fifth crossing them in a direction 20° N. of W.

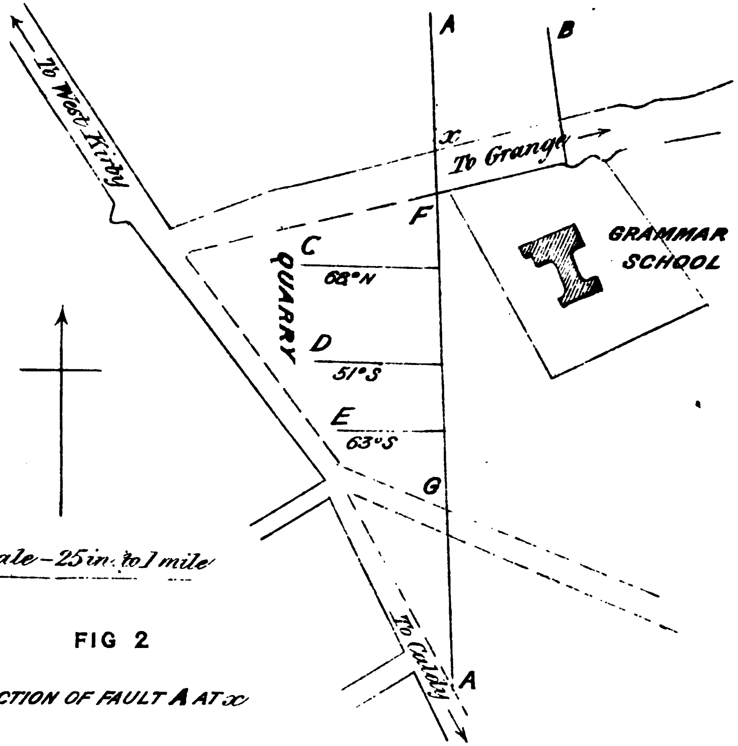
In the Quarry at Poulton, half a mile South of the above, and in the same beds, viz., the lowest part of the Keuper Sandstone, several joints at varying angles from 20° S. of W. to 25° N. of W., irregularly distributed within a space of 30 yards at the northern end of the quarry. The joints in all the above cases are vertical, and the striations horizontal, practically parallel with the bedding.

In the Quarry in Keuper Sandstone, on north side of Howbeck Road, just above St. Aidan's College, Birkenhead, a joint similar to the foregoing one, having a direction 30° W. of N. could be traced across the Quarry and on both sides Howbeck Road, and a few yards further on probably strikes the E. and W. fault which brings down the Keuper Marl against the sandstone.

On Bidston Hill, at a point in the cutting close to the windmill, an indistinctly striated joint with a direction of about 20 N. of W.

Brandreth Delph, Parbold, in the Millstone Grit; two sets of joints at right angles, both slickensided. The joints parallel to the strike have a hade perpendicular to the bedding, and are striated horizontally; those at right angles to the strike are vertical, and striated parallel to the bedding, viz., with a dip of 20° S.

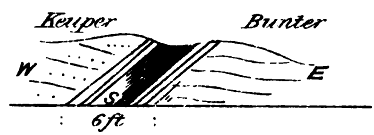
FIG. 1. PLAN OF FAULT AT CALDAY-GRANGE, WEST KIRBY, CHESHIRE



Scale—25 in. to 1 mile

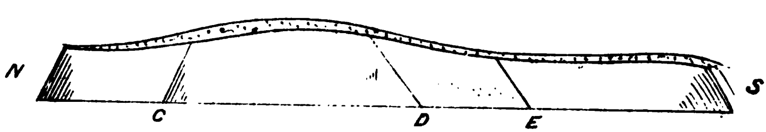
FIG 2

SECTION OF FAULT A AT x



S = SPRING

FIG 3.



ELEVATION OF FLANK OF FAULT F TO G
SHOWING CROSS FAULTS

50 100 FT

("The Calday-Grange Fault," by O. W. Jeffs.)

THE CALDAY-GRANGE FAULT, WEST KIRBY.

By Osmund W. Jeffs.

The phenomena associated with faults in the Triassic rocks are receiving attention at the hands of several members of the Society. It is thought, therefore, that a record should be made of an unusually extensive flank-exposure of a considerable fault at Calday-Grange, which was visited by the Society during their recent field meeting at Thurstaston.

The Keuper Basement Beds form the crest of the hill extending from West Kirby to Caldy. In the Survey Maps issued previously to 1884 the rock was wrongly coloured as "Pebble Beds." The extension of these beds eastward is partly bounded by the fault in question, which strikes north and south, throwing down the Keuper Basement Beds against the Bunter (AA, Fig. 1). The fault is to be seen in transverse section at the side of the road (x, Fig. 1) leading from West Kirby to the Caldy-Grange Grammar School (as shewn in section in Fig. 2). It is about 6 feet wide, filled with cleaved rock, the hade being 51° west. I have been unable to ascertain the amount of throw, which, however, must be considerable. The rock on the east of the fault is very soft and current-bedded Bunter Sandstone; that on the west is a dark red quartzose grit, containing clay pebbles, and undoubtedly belongs to the Keuper division. Where the fault crosses the roadway, there formerly (up to 1881) existed a spring (S, Fig. 2), which has now disappeared.

At a distance of 5 yards to the east, another smaller north and south fault, only 1 foot in width (B, Fig. 1.) is also seen in transverse section.

At the opposite side of the road, in a quarry at the back of the Grammar School, is the flank exposure of the main fault already referred to, the eastern face of the fault running parallel with and forming the boundary of the quarry for a distance of 135 yards (F to G on Plan, Fig. 1.) The fault rock is slickensided with striations parallel to the hade. The face is covered in places with reddish coloured clay, from 1 to 6 inches in thickness.

This fault is crossed by three smaller transverse faults (C, D, and E, Figs. 1 and 3) running east and west. The first, situated about 10 yards from the north end of the quarry, hades 68° to the north, and is covered with oblique striations dipping 70° west.* The surface is not a true plane, but undulates along the strike. At a distance of 21 yards to the south another transverse fault occurs, having a hade 51° to the south, and the third is found 9 yards further to the south, hading 63° to the south. (See Elevation, Fig. 3. The vertical scale is exaggerated.) Each of these exhibited slickensided surfaces. These transverse faults were not visible at the time of the Society's visit, being obscured by quarry débris, but the particulars given were ascertained on previous and subsequent visits, on which occasion I have to express my indebtedness to Mr. T. Mellard Reade for his assistance kindly rendered.†

Near the Waterworks on Beacon Hill several small faults occur, running transversely to the general direction of the main faults of the district, some of which present examples of highly polished slickensides. In some of these cases the two faces of the fault, or joint,

* The hades and dips are all given from a horizontal plane.

† The first of these faults was again uncovered in April, 1887.

seem to meet, and it is remarkable that such polished surfaces should result where there is no apparent throw.

In studying the Triassic rocks it is specially noticeable that they are not folded or contorted, but are broken up in definite lines by numerous faults and joints crossing each other, bringing up rocks of varying degrees of hardness to the surface, which have doubtless aided the work of denudation, and affected in some measure the scenery of the district.

NOTES ON THE EXCAVATIONS FOR THE PRESTON DOCKS.

By E. Dickson.

The River Ribble, at Preston, has excavated a valley out of the Glacial drift ¾ to 1 mile wide, and from 150 to 200 feet deep, at the bottom of which the river winds in a series of S-like curves. The channel is subject to frequent variations, although for the last 50 years the channel of the river below Preston has been fixed by the walls put in by the Ribble Navigation Company.

The formations present are (1) Upper Boulder Clay. (2) Middle Sand. (3) Lower Boulder Clay. (4) Pebble Beds of Bunter Sandstone. A large number of borings have of late years been made in the alluvium forming the lower portion of the plain, showing the deposits to consist of (1) Surface Soil. (2) River Silt. (3) Peat, in places. (4) Sand and Gravel. These deposits vary from 20 to 38 feet in thickness. The peat does not extend uniformly over the whole plain, but in patches of a greater or less area. The gravel is evidently derived

from the drift, consisting of granites, felstones, lavas, limestones, &c. It is difficult to trace the origin of many of these, but in the greater number of cases they appear to have come from the Lake District, and to a less extent from the South of Scotland. Many of the limestones have evidently come from the west of Yorkshire.

The excavation for the New Docks is entirely in the alluvial plain. The works which are situate below Preston and opposite to the present docks consist in:

(1.) Cutting a new river channel (River Diversion) 3,000 yards long and 300 feet wide, below Castle Hill, at Penwortham.

(2.) Making a Dock 3,000 feet long and 600 feet wide, to be connected with the river by means of locks and a Tidal Basin.

(3.) Filling up a portion of the present channel, and utilizing another portion as a timber dock.

A horizontal section of the south side of the Diversion extending from below Castle Hill to Hangman's Wood, a distance of about 583 yards, shows the sequence of the deposits to be—

(*a*) Surface soil.
(*b*) i., Silt.
  ii., Brown mottled sand.
(*c*) Peat.
(*d*) Sand and gravel.
(*e*) Rock.

The thickness of the deposits above the rock is about 20 to 25 feet, the average 23 feet 9 inches. The uniformity of the deposits is somewhat remarkable. The surface of the rock lies 1 ft. 6 in. to 2 ft. below Ordnance

Datum line, rising considerably above it below Castle Hill and again at Hangman's Wood (where it rises 10 ft. above O.D.), at each of which places the rock is within 1 to 2 feet of the surface of the ground. The surface of the rock is moderately even, but affords evidences of glacial action, and a rounded dome-shaped mass of rock lying about 300 yards West of Hangman's Wood, where it rises 8 feet above O.D., has every appearance of a *roche moutonnée.*

The peat on the south side of the river diversion extends for about 1,000 feet, the average thickness being 2 feet 6 inches. The base of the peat is, on the average, 10 feet above the Ordnance Datum. On the north side of the river diversion the same band of peat is visible, but commences about 250 feet further west than on the south side, and extends to a similar distance beyond the peat on the south side. The same band of peat extends eastwards to "Marsh Cottage," 200 yards north of the river diversion, where it dies away. The band just touches the south-east corner of the Dock. It would seem, then, that the peat lies in a hollow, and covers an elliptical area, thinning out towards the east and getting gradually thicker towards the west. The trees in the peat itself are mostly of small size, 12 or 15 inches in diameter being about the average. The peat seems to consist mainly of brushwood, and for the most part of hazel, from the large quantity of nuts found. No bones, or anything of interest have been found in the peat. The clay lying in places below the peat is only found for one third of the distance on the south side of the diversion, and not at all on the north side. A little is seen on the west side of the dock. The clay is a dark, stiff, blue clay. In the other parts the peat lies directly on the gravel.

The silt which underlies the surface soil and lies above the gravel, is the ordinary inundation mud formed by the overflowing of the river.

As mentioned above, the river course has constantly varied, the channel being at one time in one part, and at another time in another part of the plain. The effect of this constant changing is that the river has had from time to time to cut through the deposits which it had itself previously formed, and it is a curious coincidence that in the year 1806 (as is shewn by an old map of that date), the river channel followed practically the same course as the new river diversion. From this fact it would seem that the position of the deposits, or the deposits themselves, are not a sure and certain guide to the age of the bones, &c., found in the deposits.

The position of the trees in the gravel, the majority of which lie with their heads towards the north-east, also indicates the former channel. The trees have been brought down by the river, and lie parallel to the direction of the old river course, which, as is shewn in the old maps, made a bend to the north-east, about 200 yards west of Hangman's Wood. Many of the trees are of large size, 31 or 33 inches in diameter, mainly oak and beech. They occur at all levels in the gravel, in one part only 3 feet above rock, and frequently in the silt. The trees in the peat lie for the most part with their heads towards the north-east and east, probably owing to the prevailing winds being west or south-west.

The gravel is coarser towards the base, and many of the boulders are of large size. In places the surface of the rock is worn into hollows, probably by ice action, which are filled with pockets of sand and finer gravel. It is in the lower deposits of gravel and sand that the bones, skulls, and implements have been found. These

last-named deposits frequently show splendid instances of false bedding.

A horizontal section through the dock shows how the surface of the rock slopes towards the sea. At the east end of the dock the surface of the rock is 6 feet below O.D.; at the west end, 9 feet; at west end of Tidal Basin, 12 feet; at Chain Caul, 14 feet; and then it drops suddenly, as a boring a little to the west of the Chain Caul 27 feet below O.D., failed to reach the rock. The rock also seems to be softer westwards. The thickness of the rock is unknown. A boring was carried into the rock 107 feet without any change in its character being noticeable. A number of sections in the Tidal Basin have been made, showing the deposits in a descending order to be:—

(*a*) Light brown loamy sand.
(*b*) Dark grey sand.
(*c*) Coarse grey sand and gravel.
(*d*) Rock.

During the excavations many interesting remains have been found. The following is a list of bones obtained from the excavations up to the end of 1885, and now deposited in the Preston Museum:—

30 Antlers (pairs) of Red Deer.
50 Portions, more or less large, of Antlers of Red Deer.
25 *Urus* heads.
2 Celtic Shorthorn heads.
1 Pilot Whale head.
1 Portion of jaw of Globiocephalus Whale.
3 Vertebrae of Whale.
12 Human Skulls (one of River Drift type.)
1 Sacrum and lumbar Vertebra of Red Deer.

7 Pelves of Horse and of *Urus.*
1 Ditto of Deer.
5 Skulls of Horse.
1 Pair of Horns of Sheep.
2 Do. do. of Goat.
2 Horns of Ox.
2 Jaws of Ox.
1 Large Vertebral Spine, probably of *Urus.*
3 Leg Bones.
1 Rib of Deer.

These bones have been found in the sand and gravel, mostly in the coarse sand and gravel, usually 10 to 15 feet below the surface, and 4 to 6 feet above Ordnance Datum.

The human skulls have been carefully measured by Mr. Shortt, the Honorary Curator of the Preston Museum (to whom I am indebted for the above list), with the following result:—

No. 6.	Cranial Index...	·67	Doliocephalic.
„ 3.	... ...	·71	Subdoliocephalic.
„ 4.	... ...	·73	„
„ 1.	... ...	·76	Orthocephalic.
„ 2.	... ...	·76	„
„ 8.	... ...	·81	Brachycephalic.
„ 5.	... ...	·83	„
„ 7.	... ...	·83	„

Nos. 9 and 10 were too imperfect to be examined.

No. 2 had an aperture at the back of the head which might have been caused by a sharp instrument.

Possibly the most interesting of all the remains found in the dock excavations is a bronze, leaf-shaped spear-head, which was found at the entrance to the Tidal Basin, 19 or 20 feet below the surface, and 4 feet 6 inches below O.D. It is 9½ inches in length, and

extreme width is $1\frac{13}{16}$ inches. It has a hollow shaft, and a hole $1\frac{1}{4}$ inches from the end for attachment. The edges and point are sharp, and it does not bear the marks of injury from being rolled for a great length of time in the gravel. The material is a hard bronze, and does not, I think, contain much lead. A bronze spear-head was found a few years ago on the banks of the Ribble, at Walton-le-Dale, a valley two miles from Preston. The two, when viewed side by side, though having points of resemblance, are undoubtedly of different types.

In December last an iron axe was found in the dock excavations in the gravel. The head is attached to a hollow iron handle, surrounding the wooden haft. There is still metal present, the iron not having all been converted into oxide.

The most striking feature in the character of the remains found in the excavations is the large number of *Urus* bones. The form of the spear head, the varied character of the skulls, the presence of bones of *Urus*, with those of Celtic shorthorn, sheep, goat, red deer and horse seem to point to the conclusion that the spear head, skulls, *Urus*, and the greater part of the other bones found in the gravel all belong to the same period, viz., the later bronze period.

The following is a list of some of the shells found in the sand and silt 10 feet below the surface:—

Buccinum undatum,
Turritella terebra,
Cardium edule,
,, *echinatum,*
Anodon cygnæus,
Littorina littorea,

Natica
Tellina
Scrobicularia } Young Shells.
Mya
Mactra

In conclusion I wish to express my thanks to Mr. Beckett, the engineer on the works, for his kindness in giving me much valuable information, and to Mr. Philip Holland, F.C.S., for taking photographs of the works, typical sections, and objects found in the excavations.

ON THE OCCURRENCE OF COPPER IN THE BUNTER CONGLOMERATE OF HUNTINGTON, STAFFORDSHIRE.

BY A. TIMMINS, C.E.

THE Bunter Pebble Beds of this locality consist of massive quartzose conglomerate, which form the undulating and extensive plateau of Cannock Chase. They consist of well-rounded and water-worn pebbles of quartz, quartzite, and limestone. Besides these there are other occasional pebbles of white quartz, coal-measure sandstone, millstone grit, chert containing casts of crinoidal stems from the mountain limestone, dull red sandstone, agates and traps more or less decomposed, altered slate and jasper. These pebbles vary in size very much, and are cemented together with siliceous and calcareous matter. On the summit of Shore Hill an opening had been made for the extraction of gravel, it being found that for a certain depth from the surface the conglomerate could be picked and shovelled easily. In this pit at large intervals small

irregular patches of green carbonate of copper occur, some more or less mixed with sand. The presence of this mineral where found has doubtless resulted from the degradation of pre-existing vein lodes or aggregations in strata anterior to the Triassic age; the coating of the gravel with copper is perhaps owing to the infiltration of carbonated rain water dissolving out the copper and re-depositing it as found. There was no appearance of fissures which could suggest that the copper was due to injected thermal mineral water from below.

About 300 yards from this gravel pit the South Staffordshire Water Works Company sank a well which proved Conglomerate 225 feet, but no signs or traces of copper were met with. It proved that the Conglomerate was coarser and more compact at its base, and that a great number of stones were indented with small indents, probably owing to the excessive friction of juxtaposed stones, which would be free to oscillate before the cementing matrix had hardened and consolidated.

ON A SECTION OF BOULDER CLAY NEAR HYDE, CHESHIRE.

By J. Lomas, Assoc. N.S.S.

(Abstract).

The section is on the Middle Coal-measure series, near the Canal bank, a little on the Hyde side of Apethorne Mill.

The Clay is being worked away, and leaves a cliff about 20 feet high. It is of a stiff nature, brown in

colour, and shows no sand-beds or other evidence of break of continuity in accumulation.

Boulders are very numerous, and some of a very large size, the majority being scratched and polished. No shells have been found*. The prevailing rock is a dark blue *Hornblendic Andesite*, which weathers white or buff. It contains crystals of Orthoclase and Plagioclase Felspars, and decomposes along cracks into a greenish product. Specific gravity, 2·74. In thin sections it shows beautiful examples of vermicular chlorite. According to Prof. Bonney, F.R.S., the rock does not occur in Cumberland, but is met with just across the border.

Other rocks found are:—

Granites (red and grey).
Syenite.
Quartz Felsite, rather abundant.
Diorite.
Basalt.
Serpentine.
Millstone Grit, very abundant.
Coal-measure Sandstone (Ganister, &c.)
Quartzites.
Permian Sandstone, a boulder well scratched and polished, one half of which contained numerous fossils.
Carboniferous Limestone containing fossils.
Chert., *Shales.*, *Ironstones.*, *Coal.* — Very abundant, and mostly sub-angular.

Mr. T. Mellard Reade, C.E., F.G.S., is of opinion that the rocks are mostly of Scottish origin, but contain many species from the Pennine Chain.

*Since writing the above Mr. P. F. Kendall, of Owens' College, has found a fragment of *Pecten opercularis*.

SOME USES OF THE CARBONIFEROUS LIMESTONE.

By J. J. Fitzpatrick.

The Carboniferous Limestone offers to the student a vast field for research and inquiry, not only because it contains many of the most interesting fossils that are to be found in the rocks, but also from the many qualities and properties of a beneficial nature to mankind that it possesses. A few remarks, therefore, upon these strata may be of interest.

It is well known that Limestone, in a wonderful degree, conduces to the wealth and prosperity of the country. If it is only considered as a stone suitable for building purposes, it must be admitted that it will bear favourable comparison with any other description of stone that may be mentioned. Experience teaches that, in many respects, it is more suitable and far more durable than granite. The resistance it offers to weathering and to the general waste caused by atmospheric exposure, makes it much sought after by the practical builder, and by all who have tested its admirable qualities as a building stone. Then again, it is found in the form of marble, with its many varieties and numerous colours, which may be seen in the simple parlour mantelpiece, or in the shape of artistic statuary, which although composed of true limestone, yet it cannot be classed as Carboniferous; but it would be an omission not to mention this description of marble, as from it such statues as the Venus of Milo, the Venus of Medici, the Laocoon, and the Apollo Belvedere are formed. Many of these sculptures have lasted for thousands of years, and may endure for centuries to come.

Derbyshire and North Wales supply the greater part of England with lime for cementing and building purposes, and there is no danger of the supply ever running short, as it may be said to be inexhaustible.

Another most important reason why these rocks should be considered useful to humanity will now be given, and the consideration of this is certainly the most pleasing, as it treats of the wonderful curative properties possessed by certain mineral waters which arise from the Limestone rocks, and which are of inestimable benefit to suffering humanity. I refer to thermal waters, and in order to illustrate this matter clearly I will select the famous watering place Buxton to show how useful these tepid waters are in many forms of disease and sickness.

Before giving an account of these springs a few words about Buxton itself may be acceptable. Its situation is such that it is sheltered on every side by hills consisting of Limestone, Millstone Grit and Yoredale Rocks. In the time of the Romans it was used as a watering place, and even then it was renowned for the medicinal and curative properties of its waters. Buxton is situated in the valley of the River Wye, at a height of 1000 feet above sea level, in the midst of wild and picturesque scenery.

Very little is known of the Carboniferous Limestone of the district, and it certainly offers opportunities for any one who has the ability and inclination to work up the locality and thereby contribute a little knowledge about this interesting district. The rocks vary very much in hardness, and I have found them so hard in several quarries that it was with difficulty fossils could be obtained. The nearest quarries to Buxton in which fossils may

be found, are situated at a distance of a mile and a half, or two miles, out of the town, and the richest beds of fossils are in a rockery in the pleasure gardens where the natural rocks are exposed, consisting of one mass of fossils, chiefly encrinites, with *Productus* and *Spirifera.*

The flow of water from these springs is estimated at about 150 gallons per minute, and the temperature is always 81° Fahr. The source of the waters has been the cause of much discussion, and their effect upon the human body is so powerful that no delicate person should bathe in them without first consulting a medical man. The waters spring from the Limestone, and by bathing in and drinking them the most wonderful cures are effected. In chronic cases, where cure is impossible, alleviation, or a lessening of the ailment, is sure to take place by their remarkable curative powers. A bath has a most exhilarating effect, especially in the case of a person who can swim.

The waters are noted for the large quantity of nitrogen they contain. The principal constituents are Carbonate of Lime, Carbonate of Magnesia, Chloride of Sodium, Chloride of Calcium, Silica, Peroxide of Iron, Sulphate of Lime and Chloride of Potassium. In chemical composition and the medicinal uses to which they are applied they resemble the thermal waters of some famous German watering places.

As to the origin of the springs: the rainfall of the district is very great. This water descends through cracks and fissures in the limestone, and through the sandstone, until it gets its natural warmth by coming in contact with heated rocks at a considerable depth. It then returns to the surface and escapes in the form of these tepid springs.

THE BASE OF THE CARBONIFEROUS LIMESTONE.

By Charles Ricketts, M.D., F.G.S.

It is well known that the different divisions of the Carboniferous System have been deposited on those of older formations,—unconformably, and on their greatly eroded surfaces and edges. The Coal-measures, at the southern extremity of the North-Western Carboniferous area, overlie what was a narrow tract of land extending from Leicester to the mountainous district of North Wales, forming at the time of the deposition of the limestone an isthmus, separating the northern from the southern division. During the whole period of the deposition of the Carboniferous Limestone this land was never submerged. Coal measures rest along this belt directly upon eroded surfaces of the rocks of the Longmynd, and of the Stiper Stones; on the Lower and Upper Silurians, and on Old Red Sandstone.*

The Carboniferous Limestone also is situated upon eroded surfaces of older rocks. It rests against the metamorphic rocks of Anglesey; on Lower and Upper Silurians in Shropshire and North Wales, also in Westmoreland, Yorkshire, &c. In several localities beds of sandstone and conglomerate of a deep red colour are situated beneath the Limestone. Wherever these strata exist they lie between the Silurians and the Carboniferous formations, and, being of this deep red colour, were called by older geologists "Old Red Sandstone," the term leading them to be very generally

* See "Memoir on the South Staffordshire Coalfields," by J. B. Jukes, F.R.S. Page 12.

considered as the representatives of the Old Red Sandstone such as that of Scotland and Herefordshire. Though calling these beds the "Old Red Sandstone formation," Professor John Phillips * has described them in such terms as to lead to the inference that they must be referred to the Carboniferous system, which in these localities is "characterized by the prevalence of coal, limestone, and red sandstone," he considered them as "almost exclusively a valley deposit;" "they are confined to valleys in the slate formation and never follow the rock to its escarpments on high ground." A name previously appropriated had been wrongly given to these deposits, consequently, until quite recently they were considered as representatives of the older formation. The explanation, as I interpret the statement of Phillips, is now recognized by members of the staff of the Geological Survey as correct, though the wrong designation still remains on the maps.

The locality best known to our members in which these red beds occur, is beneath the Eglwyseg rocks near Llangollen. Though no section is now exposed, the area over which they extend is indicated by the deep red colour of the soil. Judging from exposures by the sides of a cart road, and from the contents of a mound, formed by the excavations made to utilize a spring, the deposit consists of sub-angular pebbles derived from Silurian rocks, iron stained throughout their whole substance, and embedded chiefly in a dark red clay. Some years ago it was observed that the strata in a small section dipped beneath the limestone, and in the same direction, being at right angles to the general direction of the dip of the Silurian rocks on which they

* "Geology of Yorkshire," part ii., pages 11, &c. Trans. Geol. Soc., vol. iii,, page 4,

rest. It was at such an angle that an extension of the beds westward would cause them to abut against the adjoining hills of Wenlock rock. To describe it in other words, they are situated in an excavation eroded in Silurian rocks, and in all probability filled the bottom of a pre-Carboniferous valley. The exact junction of these "red basement beds" with the Carboniferous Limestone was not observed, being covered with talus; the lowest slab of limestone met with has 28 per cent. of brown mud entering into its composition.

Similar red beds occur near Kirkby-Lonsdale, Westmoreland, and are well exposed at the village of Barbon, in the watercourse called Barbon Beck. They are composed of pebbles, apparently Silurian, with the angles rounded, as are those beneath the Eglwyseg escarpment, and many of the blocks are larger than any met with there. They are stained in the same way, but frequently the colouring does not extend throughout. Interstices between the larger pebbles are filled up with smaller ones, rounded or subangular, and partially cemented together, or the space is sometimes filled with calcite. Some of the pebbles bear indentations on them, and are cracked, it may be, into several pieces, but with very slight displacement of the parts. Their state is similar to those referred to by Professor James Thomson, F.R.S., as occurring in the Old Red Sandstone, at Aberfoyle;* and is like some in a band of pebbles in the Middle Bunter, near Prescot Workhouse.† Phillips noticed these impressions and, I think, gave the right explanation of their cause when he "imagined that one pebble had indented another."

* "British Association Report," 1882; page 536. Mr. W. Topley, F.G.S., in the same Report gives reference to numerous authorities for the occurrence of these phenomena.

† C. Ricketts. "Proceedings Liverpool Geol. Society, vol. iv., page 448.

At Shap Wells in Westmoreland the representatives of these "Red Basement Beds" overlie eroded Lower Silurian strata; they occur in Wastdale Beck (a stream having its origin in Wastdale Pike), near the Hotel, as a brecciated conglomerate formed partly of pebbles from Lower Silurian Rocks, the angles of which are rounded, and also of angular fragments derived from the disintegration of Shap granite, amongst which the characteristic felspar is conspicuous. Though the locality where this breccia occurs must subsequently have been thickly covered with Limestone and other Carboniferous strata, which have since been denuded, Wastdale Beck flows in a course nearly identical with that it must have taken previous to the deposition of the Limestone. The red beds for the most part consist of red coloured sandstone lying horizontally or nearly so; they may be traced from immediately east of Shap Wells to Tebay, four miles to the south-east. Professor H. Alleyne Nicholson has observed "an occasional crystal of flesh coloured Felspar," about midway between Shap Wells and Tebay; * this is important as tending to determine the direction the stream ran by which these sands, &c., were brought down; viz., in a south-east direction, as its present representative, the Birkbeck, does now. These red rocks occur under similar conditions in other places, at Kendal, Sedburgh, Denbigh, Ruthin, &c.

The base of the Carboniferous Limestone in North Wales is seldom seen at the juncture where it rests on the Silurian rocks, but can be frequently observed in the Dales deeply cut in the Ingleborough mountain, south-west Yorkshire. The only place met with in Wales was on the southern bank of the Dee, a short distance from the aqueduct. This locality (Fron-y-Cysyllte) Mr. G. H.

* "Geology of Cumberland and Westmoreland," page 74.

Morton shews was much higher, and "formed dry land during the deposition of the lowest limestone on the north-west,"* in the Eglwyseg escarpment. On dissolving the lime with acid a large proportion of its ingredients proved to be small fragments of Wenlock shale. A similar instance occurs at the foot of Brackenbottom Scar, near Horton, in Ribblesdale, where a stream, a feeder to the Ribble, issues from beneath the limestone at its junction with the Lower Silurian rocks. One example contained 52 per cent. of this grit.

In the formation of the Ingleborough mountain, and the contiguous ones of Whernside and Penigent, an immense amount of material has been removed from above the Limestone. Depression progressed in accordance with the deposition of the Carboniferous strata; and it may be maintained that elevation has occurred as a natural consequence of the removal of pressure caused by their denudation. Very restricted areas forming the summits of each of these hills remain a record that the Yoredales and Millstone Grit once overspread the whole district; and the coalfield of Ingleton and Burton, in Lonsdale, on the downthrow of the Great Craven fault, indicates that a great thickness of Coal-measures must also have accumulated above these lower Carboniferous strata, not a particle of which now remains.

Professor John Phillips has estimated that "the effect of this fault has been to throw down the strata of Ingleborough to the south as much as three thousand feet, so as to bury its highest rock below the thick group of Coal-measures which are worked below Ingleton."†

* "The Carboniferous Limestone and Cefn-y-Fedw Sandstone of North Wales," page 77.

† "The Rivers, Mountains, and Sea-Coast of Yorkshire;" page 35,

Besides the removal of these later carboniferous deposits, the streams or "becks" have formed valleys or "dales" cutting through the whole thickness (about 600 feet) of the Carboniferous Limestone, and into the Upper and Lower Silurian strata which form its base.* Passing by the Ingleton Limestone Quarry, and across the fault secondary to the Great Craven fault, on entering the Recreation Grounds, the Lower Silurian slates and sandstones, raised to a high angle, have been cut deeply into by the stream; the perpendicular sides of the gorge giving some idea, on a small scale, of what the term cañon means in American geology. Above the waterfall the valley slopes outwards, the bottom being formed of the older rocks, whilst a little higher and resting on their eroded edges the flanks consist of Carboniferous Limestone. The junction of the Limestone with the Silurian may be traced up Chapeldale towards Weathercote, but can be studied best at the exit of small streams issuing from beneath the limestone, and over the slates. In an instance, not far from the house called Beezley's, the lowest stratum referable to the Carboniferous system is a horizontal bed about three feet thick consisting of small angular fragments derived from Silurian rocks, cemented together with mud from the same; no calcareous matter enters into its composition. This is overlaid by a bed of limestone 3½ feet thick, containing many water-worn pebbles from two to four inches in diameter. This is followed by a bed, four feet thick, of brown calcareous sandstone containing 14 per cent. of carbonate of lime. Above that for six feet is a limestone completely packed with small pebbles. Higher up the beds are obscured by talus, or as called in the north "screes."

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* Professor T. Mc K. Hughes has given a detailed description of these Silurian rocks; Geol. Mag., vol. iv., page 346.

Norber Scar, a promontory forming the western approach to Crummack Dale, has a stream issuing from beneath the Limestone which has cut a channel through Lower Silurian slates, and has formed a section more interesting than it is at present in my power to describe. The beds at the base of the Carboniferous Limestone vary greatly in composition; the lowest, resting on the slate, is thin and composed entirely of Silurian mud, hard and consolidated, and does not contain lime. I have a record of the occurrence at ten inches above the base of angular fragments of various sizes up to three inches or more in diameter, cemented by mud and carbonate of lime; above that, at two feet from the base, is a thin bed of sandy limestone followed by beds of limestone containing innumerable rounded pebbles. A remarkable circumstance is the occurrence of rounded fragments of limestone apparently shaped as are the balls of clay, so commonly observed in different places on the shores of the Mersey, by the rolling action of the waves.

As a general rule the pebbles embedded in the Limestone gradually dimish in size the higher they are above the base, and small fragments can be traced near Ingleton to a height of forty feet. Near Norber a little way up the valley there is a bed full of large fragments of any size up to three and even five feet; it occurs at a height of twenty-five feet above the base exposed immediately beneath it.

Conclusion.—It appears that in the long interval between the termination of the deposit of the Upper Silurians and Old Red Sandstone, and the commencement of that of the Carboniferous series of strata, a period elapsed during which the former, and with them to a great extent the Lower Silurians, were exposed to a very great amount of denudation consequent upon their being

raised above the sea level; thus hills of a considerable height were formed; the streams running in these valleys carried away the materials which atmospheric disintegration had loosened. These channels must have been excavated to a great depth—near Llangollen probably to considerably more than 1000 feet; yet the rivers or brooks there or elsewhere do not appear to have been very long, for the pebbles composing the "Red Basement Beds" are in each place of local origin.

Higher up the flanks of the valleys, where they would have been removed from the influence of these river currents, the limestone rests directly upon the older denuded rocks, but the base of it is in an impure state, consisting, it may be to the extent of 50 per cent. or more, of rounded fragments derived from the rock on which it rests. These fragments are but little altered by weathering, and contrast greatly with those of the Red Basement Beds. Their size generally diminishes the higher they are situated above the base, minute ones being detected at a height of 40 or 50 feet at the foot of Ingleborough.

It is desirable to notice how greatly the present contour of the land is due to the erosion which occurred prior to the deposition of the Carboniferous strata; it may be that water finding a ready access between the limestone and the underlying rocks, both, but the limestone especially, were exposed more readily to disintegration, and thus portions of old channels are again made to reappear. This has been shewn to have taken place to some extent near Llangollen. The red beds near Kirkby Lonsdale are situated along the valley and take a direction similar to that in which the river Lune now runs; it is probable Phillips is correct in his suggestion that

the origin of the deposit "was confined to what is now the track of the Lune." *

The occurrence of occasional crystals of flesh-coloured Felspar, referred to by Professor Nicholson, renders it probable that a pre-carboniferous river took a course in a southerly direction, similar to that of the Birkbeck, a tributary of the Lune; and it appears certain that Wastdale Beck, a feeder of the Birkbeck, having its origin in Wastdale Pike, and passing by Shap Wells, runs in a channel greatly hollowed out prior to the deposition of the Carboniferous Limestone.

The impervious nature of the Silurian rocks has frequently had influence in determining the situation at which streams or springs issue. In the Ingleborough district it is a common occurrence for the water to flow out at the line of division between them and the limestone.

The course of the stream, or "beck," flowing through Chapel Dale is remarkable; it enters the limestone to the north of Weathercote, and for about a third of a mile is lost entirely; it then reappears for an instant in Weathercote Cave as a waterfall (the cave is a moderately-sized chamber, open at the top); the water falling to the bottom immediately disappears for half a mile or more, when it reappears, and, flowing over Silurian rocks for a space, again disappears for a short distance beneath limestone, afterwards continuing its course by Ingleton to the river Greta, a tributary of the Lune. This is by no means an exceptional example of a stream passing for a time beneath the limestone on the platform of older rocks.

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* Trans. Geol. Soc., vol. iii., p. 7.

The frequency of caverns in the district has been referred to by Wordsworth :—

> "In Craven's wilds is many a den
> To shelter persecuted men,
> Far underground is many a cave
> Where they might lie as in the grave."

Recent explorations in Victoria Cave, Settle, have demonstrated that this is no fanciful suggestion of the poet; the very circumstances alluded to are proved to have actually occurred there.

THE MICROSCOPIC CHARACTERS OF THE CEFN-Y-FEDW SANDSTONES OF DENBIGHSHIRE AND FLINTSHIRE.

By G. H. Morton, F.G.S.

The Sandstones and Shales forming the Cefn-y-Fedw Sandstone of North Wales have been fully described in a series of papers published in the "Proceedings" of this Society during the past ten years. In a paper "On the Strata between the Carboniferous Limestone and the Coal-measures of Denbighshire and Flintshire," * read before the Manchester Geological Society, I gave a *resumé* of my former communications on the subject, and the subdivisions of the formation were shewn as they occur in eight different localities in these counties, so that reference to these papers will furnish full details as to the geological position of the sandstones and

* Trans. Manc. Geol. Soc., vol. xvii., p. 74.

other rocks described. The following classification of the strata may, however, be useful. Although on the same horizon, there is a great difference in the lithological characters of the subdivisions in Denbighshire when compared with those in Flintshire.

The Sandstones and other rocks from the Cefn-y-Fedw formation are interesting, as they show the passage of sandstone into quartzite, but more particularly on account of showing the passage of fine-grained sandstone into chert. The rocks are of a very varying character, and those described are only typical examples of a far greater variety that might be easily collected to show the most minute shades of difference.

TABULAR VIEW OF THE CEFN-Y-FEDW SANDSTONE IN DENBIGHSHIRE AND FLINTSHIRE.

Llangollen & Ruabon, Denbighshire.	*South of Flintshire.*	*North of Flintshire.*
Aqueduct Grit.	Aqueduct Grit.	Gwespyr Sandstone.
Upper Shale. Dee Bridge Sandstone.	Upper Sandstone and Shale.	
Middle Sandstone. Cherty Sandstone.	Cherty Shale.	Cherty Sandstone.
Lower Sandstone and Conglomerate.	Lower Sandstone and Conglomerate.	
Arenaceous Limestone.	Arenaceous Limestone.	Upper Black Limestone.

1.—SOFT RED SANDSTONE, BALLANE FARM, TREFLACH.

Lower Sandstone and Conglomerate.

Light red, soft sandstone, composed of rounded and angular grains of quartz from $\frac{1}{100}$ to $\frac{1}{200}$ of an inch in diameter. Some few are smaller, but the absence of

minute fragments is remarkable. The grains seem all to have been water-worn, but a frosting of silica covers the surface, and there are a few crystallized faces. No other mineral except the ferric oxide, which coats the quartz.

The rock closely resembles the soft red sandstone of the Upper Bunter around Liverpool.

2.—Red Sandstone, Old Tramway, Treflach.

Lower Sandstone and Conglomerate.

Light red sandstone, with small quartz pebbles, composed of rounded and angular grains of quartz from $\frac{1}{75}$ to $\frac{1}{500}$ of an inch in diameter. The larger grains are well water-worn, and even many of the small ones rounded; crystallized faces occur on the small grains. There are numerous minute fragments of quartz and grains of kaolin, and the whole tinted with ferric oxide. This sandstone is remarkable on account of the great difference in the size of the grains and the water-worn character of the largest of them.

3.—Light yellow Sandstone, Sweeney Mountain, Oswestry.

Sweeney Mountain Sandstone.

Light yellow sandstone, composed of rounded and angular grains of quartz from $\frac{1}{50}$ to $\frac{1}{250}$ of an inch in diameter, and a quartz dust $\frac{1}{1000}$ to $\frac{1}{5000}$ of an inch. The largest grains are water-worn, and crystallized faces of frequent occurrence. There is a great gap between the grains and the dust. There are some small grains of manganite or hematite which rusts the quartz around it, and gives the rock a yellow tinge.

This sandstone is often made up of grains $\frac{1}{50}$ to $\frac{1}{250}$ of an inch in diameter, which are well water-worn and quite incoherent. In this soft condition the sand is used for glass making.

4.—White Sandstone, Sweeney Mountain, Oswestry.

Summer-house Sandstone.

White calcareous sandstone, composed of rounded and angular grains of quartz. The grains vary from $\frac{1}{50}$ to $\frac{1}{200}$ of an inch and under in diameter. The matrix is like white calcite when seen in minute fragments. Manganite or hematite occurs in rusted grains.

The cleavage is occasionally continuous along one plane, and gives a shining appearance to flat surfaces.

5.—Light red Sandstone, Bron-y-Gell, Morda Ravine, Oswestry.

Lower Sandstone and Conglomerate.

Light red mottled sandstone, composed of grains of quartz and much red orthoclase, which shows the cleavage planes, and gives a reddish colour to the rock. The quartz grains are $\frac{1}{100}$ of an inch and less in diameter with many minute splinters, and the grains present crystallized faces. There are a few grains of white kaolin which may have resulted from the red orthoclase decomposing.

6.—White Calcareous Sandstone, School, Bron-y-Garth.

Lower Sandstone and Conglomerate.

Fine-grained white calcareous sandstone, composed of rounded grains of quartz about $\frac{1}{100}$ of an inch in diameter, in a calcite matrix.

This rock is almost a limestone, with many rounded grains of quartz, and it contains spicules of sponges, which may be usually seen in hand specimens.

7.—Hard white Sandstone, Eglwyseg Ridge, Llangollen.

Lower Sandstone and Conglomerate.

Hard white sandstone or quartzite, composed of rounded grains of quartz about $\frac{1}{100}$ of an inch in diameter in a matrix of transparent quartz. Crystallized faces on the grains in small open spaces, where the grains are united and the matrix not present.

This sandstone is remarkable for the great number of white quartz pebbles it contains, and which occasionally fracture across when the rock is broken, but usually are detached.

8.—Calcareous Sandstone, Eglwyseg Ridge, Llangollen.

Arenaceous Limestone.

Coarse grey sandstone, composed of rounded grains of quartz in a limestone matrix. The grains are all waterworn and vary from $\frac{1}{100}$ to $\frac{1}{200}$ of an inch in diameter, giving the rock an oolitic appearance when seen under the microscope.

9.—Coarse yellow Grit, Tyfynuchaf, Ruabon.

Aqueduct Grit.

Coarse yellow grit, composed of quartz grains with a matrix of kaolin. The grains are from $\frac{1}{50}$ to $\frac{1}{500}$ of an inch in diameter and mostly angular, but a few present a rounded appearance, and crystallized faces rare. There are a few flakes of white mica and grains of tourmaline.

This rock is very like the Millstone Grit of the south-west of Lancashire, and it occurs in several localities about Ruabon, and it is the highest subdivision of the Cefn-y-Fedw Sandstone.

10.—FINE GREY SANDSTONE, RIVER TERRIG, TRYDDYN.

Upper Cefn-y-Fedw Sandstone (base of section).

Fine-grained grey sandstone, composed of rounded and angular grains of quartz from $\frac{1}{200}$ of an inch, gradually decreasing to a dust $\frac{1}{5000}$ in diameter. Excepting the larger grains they are angular, and possess bright fractures. A few of the grains present crystallized faces, there is a little kaolin, and some minute bright black grains may be tourmaline.

This rock is very hard, and approaches a quartzite.

11.—GREY QUARTZITE, MOEL-Y-GAER, FLINTSHIRE.

Lower Sandstone and Conglomerate.

Fine-grained grey quartzite, composed of minute grains of quartz, in a compact matrix of similar glassy quartz. The grains are about $\frac{1}{300}$ of an inch and under in diameter. No crystallized faces could, under these conditions, be observed on the grains, but the sides of the joints in the quartzite are covered with the terminations of crystals.

12.—LIGHT YELLOW SANDSTONE, PANT-Y-GOP, MOEL-Y-GAER, FLINTSHIRE.

Lower Sandstone and Conglomerate.

Very light yellow sandstone, composed of rounded and angular grains of quartz about $\frac{1}{100}$ of an inch in diameter, very regular in size, and with many crystallized faces. The grains seem water-worn, and a little hydrated ferric oxide gives a yellow tinge.

This sandstone was probably the normal condition of the rock before converted into quartzite by the infiltration of silica and the formation of a matrix.

13.—White Chert, Moel-y-Gaer, Flintshire.

Lower Sandstone and Conglomerate.

White, or grey chert, composed of fine grains of quartz $\frac{1}{500}$ of an inch and under in diameter, in a siliceous matrix with spicules of sponges. It is evidently a very fine grained sandstone rendered compact by an infiltration of silica.

14.—Grey Chert, Moel-y-Gaer, Flintshire.

Lower Sandstone and Conglomerate.

Light grey chert, composed of a siliceous matrix with spicules of sponges, and such minute grains of quartz that they can scarcely be distinguished under the microscope. Although principally composed of chert, there is probably some kaolin, and the rock has been altered by a siliceous infiltration. This composition is confirmed by the following analysis, for which I am indebted to Dr. George Tate, F.C.S.:—

Silica	92·10	per cent.*
Alumina	1·67	„
Oxide of Iron	3·28	„
Lime	1·40	„
Magnesia	·54	„
Phosphoric Acid	·04	„
Loss on Ignition, Water, &c.	1·10	„
Potash	·38	„
	100·51	„

* 7·40 per cent. of silica was dissolved by a 10 per cent. solution of caustic soda.

15.—Red Sandstone, Moel Findeg, Mold.

Arenaceous Limestone.

Red sandstone with small quartz pebbles, composed of rounded and angular grains of quartz from $\frac{1}{75}$ to $\frac{1}{800}$ of an inch in diameter, and minute fragments to less than $\frac{1}{1000}$ of an inch. Many of the grains have crystallized faces, and a glazed appearance in consequence of deposited quartz. The grains are coated with ferric oxide, and there is a little kaolin asssociated with them.

This sandstone resembles the Pebble-beds of the Bunter around Liverpool, but the white quartz forming the pebbles is different.

16.—Brown Chert, Gronant, Prestatyn.

Cherty Sandstone.

Brown or black chert, interbedded with a very fine grained sandstone of the same colour, composed of minute grains of quartz in a dark siliceous matrix containing spicules of sponges. Both the chert and the sandstone occur in the same beds, which vary from a few inches to a foot in thickness. The chert occurs in the middle of each bed, and effervesces slightly in acid.

This rock is quarried, and square sets of it are sent to the Potteries, where it is used in the construction of grinding-floors.

17.—Fine-grained Sandstone, Gwespyr, Prestatyn.

Gwespyr Sandstone.

Fine-grained, greenish-grey sandstone, composed of small grains and minute splinters of quartz from $\frac{1}{100}$ to $\frac{1}{1000}$ of an inch and under in diameter, containing many crystallized faces, and some crystals showing the prism with termination. There is a matrix of white kaolin,

grains of a brown decomposed substance, and flakes of white mica.

This rock is extensively quarried, and much used as a building stone in the north of Flintshire. I am indebted to Dr. George Tate, F.C.S., for the following analysis:—

	Per Cent.
Silica	83·30
Alumina	8·25
Iron, expressed as peroxide	3·35
Magnesia	1·65
Lime and Manganese ... traces only	—
Loss on ignition, water with slight trace of Carbonic acid	2·60
Alkalies—Soda, with bare trace of Potash	1·90
	101·05

Hydrochloric Acid dissolved—

Silica	·20	per Cent.
Alumina	2·29	„
Oxide of Iron	2·71	„
Magnesia	·65	„

18.—Fine white Sand, Holywell.

Derived from Cefn-y-Fedw Sandstone, and occurs in fissures in Carboniferous Limestone.

Fine-grained white sand, composed of minute grains of quartz from $\frac{1}{1000}$ to $\frac{1}{2000}$, and a dust from $\frac{1}{5000}$ to $\frac{1}{10000}$ of an inch in diameter. It is almost pure silica, and for the most part so fine as to resemble flour.

Veins of this sand occur near Mold and at Meliden, and it is said to be used for glass making.

THE MICROSCOPIC CHARACTERS OF THE MILLSTONE GRIT OF SOUTH-WEST LANCASHIRE.

By G. H. Morton, F.G.S.

The Millstone Grit of south-west Lancashire is exposed in three well-known areas, viz.:—Knowsley Park, Grimshaw Delph, and Parbold, both the latter being to the east and north-east of Wigan.

1.—Coarse grey Grit, Riding Hill, Knowsley Park.

Millstone Grit (Upper beds).

Coarse grey grit, composed of angular grains of quartz from $\frac{1}{50}$ to $\frac{1}{100}$ of an inch and under in diameter, with numerous minute crystallized faces. There are some grains of white kaolin, flakes of white mica, and a few of pink tourmaline, and probably hornblende.

2.—Fine Grey Grit, Stand Quarry, Knowsley Park.

Millstone Grit (Lowest beds).

Fine-grained grey grit, composed of angular grains of quartz from $\frac{1}{100}$ to $\frac{1}{200}$ of an inch and less in diameter, and many minute splinters, all of which adhere closely together. There are grains of white kaolin, small flakes of white mica, and a few of black, green, and pink tourmaline, and perhaps hornblende.

3.—Fine grey Grit, Grimshaw Delph, near Wigan.

Millstone Grit (Upper beds).

Fine-grained light grey grit, composed of angular grains of quartz from $\frac{1}{100}$ to $\frac{1}{200}$ of an inch and less in diameter, and many minute splinters, all of which adhere closely

together. There are grains of white kaolin, some white mica, tourmaline, and hornblende. It is much like the grit at the Stand quarry, though lighter, in consequence of the absence of the dark coloured minerals, and no crystallized faces being observed on the quartz.

4.—Grey Flaggy Grit, Grimshaw Delph, near Wigan.

Millstone Grit (Upper beds).

Micaceous grey flaggy grit, which is of exactly the same composition as No. 3, but that it contains a considerable amount of white mica, along planes from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch apart, causing the rock to split up in rough slabs or flags. Tourmaline and hornblende occur in small grains.

5.—Coarse grey Grit, Brandreth Delph, Parbold.

Millstone Grit.

Coarse grey grit, of a reddish tinge, composed of angular and rounded grains of quartz, some of which are $\frac{1}{6}$ of an inch in diameter, and gradually decrease to fragments $\frac{1}{1000}$ of an inch. A few crystallized faces occur. There are grains of red orthoclase showing cleavage planes, white, yellow, and pink kaolin, tourmaline and mica.

6.—Coarse grey Grit, Brandreth Delph, Parbold.

Millstone Grit.

Coarse grey grit, of a yellowish tinge, which is not so coarse as No. 5, the grains varying from $\frac{1}{8}$ of an inch in diameter to minute splinters, and the kaolin is white and yellow. No crystallized faces occur on the quartz, but tourmaline and mica are present.

7.—Fine grey Sandstone, Stoney Lane, Parbold.
Millstone Grit.

Fine-grained grey grit, with a pink tinge, composed of angular and rounded grains of quartz about $\frac{1}{100}$ of an inch in diameter. There are also pink and white kaolin, some flakes of mica, and grains of tourmaline. The grains of quartz are more rounded than in the specimens from other localities.

8.—Coarse grey Grit, Harrop Hill, Parbold.
Millstone Grit.

Coarse-grained, reddish grey grit, composed of angular grains of quartz from $\frac{1}{6}$ and $\frac{1}{25}$ to $\frac{1}{1000}$ of an inch in diameter, though the largest are water-worn, and a few grains present crystallized faces. There is kaolin, of white, yellow and red colours, which gives a warm tint to the rock.

9.—Coarse red Grit, Harrop Hill, Parbold.
Millstone Grit.

Coarse-grained dark red grit, similar to No. 8, but with a much greater quantity of red kaolin, which imparts that colour to the rock. There are, however, no grains of quartz so large as $\frac{1}{6}$ of an inch, and the rock seems harder, for the fracture often passes through the largest grains without detaching them from the kaolin and ferric oxide forming the matrix.

10.—Coarse Grit, Houghton Tower, Preston.
Millstone Grit.

Very coarse grit, composed of grains of quartz from $\frac{1}{6}$ and $\frac{1}{10}$ to $\frac{1}{100}$ of an inch in diameter, and many small splintery fragments. Although some are decidedly rounded, there are many that do not appear to be so. The largest grains, though angular, are a little water-

worn. There is red orthoclase showing cleavage planes and some flakes of white mica.

The microscopic character of the Millstone Grit of south-west Lancashire much resembles the upper portion of the Cefn-y-Fedw Sandstone, particularly that described as forming the Aqueduct Grit near Ruabon and Mold. The grains of quartz vary much in size, and are for the most part angular and but slightly water-worn. Although some of the grains have crystallized faces, they are not frequent, and might easily be overlooked. Orthoclase of a reddish shade occurs, and often exhibits the cleavage planes, but it has generally been decomposed to kaolin, and forms a matrix in which the quartz is closely embedded. There is usually a little mica and the granitic derivation obvious. There are occasional grains of ferric oxide, tourmaline, and perhaps hornblende, but they form a very minute fraction of the rock.

No well-marked distinction can be made between Grits and Sandstones of general application, for in many rocks there are both angular and rounded grains of quartz, and it is often difficult to ascertain whether they have been water-worn when the original surfaces have been covered by a film of more recently deposited quartz.

The Sandstones of the Coal-measures.

These consist of various coarse and fine-grained sandstones of a grey colour, but often weathered to a yellow or brown shade. They are similar to the fine-grained sandstones of the Millstone Grit. The grains of quartz often present crystallized faces, and there is more or less kaolin with flakes of mica. Iron occurs as the protoxide, and in the weathered rocks as the per-oxide.

IRON AS A COLOURING MATTER OF ROCKS.

By A. Norman Tate, F.I.C., F.C.S., &c.

Although other metallic compounds give colour to some minerals, iron in its several states of combination is *the* colouring matter of most rocks, and a great variety of tints is exhibited according as it is acted upon by different natural agencies.

The following reactions (these were shown by experiments) will serve to illustrate some of the changes of colour due to the presence of iron:—

(*a*) A solution of a ferrous salt (protosalt of iron), when left exposed to the air, oxidises and throws down a precipitate of a yellowish or reddish colour.

(*b*) A similar solution, treated with an alkali or alkaline earth, deposits a greenish or blueish-green precipitate, which, exposed to the air in a moist condition, gradually changes its colour to yellow or red.

(*c*) This precipitate, or any ferrous salt, such as the grey or nearly colourless carbonate, or the green sulphate, heated in presence of oxygen or air, becomes of a deep red or reddish-brown colour.

(*d*) A solution of a ferric salt (persalt of iron), acted on by an alkali or alkaline earth, gives a precipitate of a yellowish or reddish tint.

(*e*) The colour of the several precipitates varies much with rate of deposit, degree of concentration of solution, temperature of solution, and other circumstances; heat and degree of concentration having, for instance, the effect of deepening the colour of precipitates from ferric salts.

(*f*) Organic matters and water in contact with ferric compounds reduce them to a lower state of oxidation. Ferrous oxide is soluble in organic acids and in carbonic acid.

(*g*) The presence of organic matter interferes with the precipitation of iron from its solutions.

(*h*) Organic matters and moisture reduce sulphates to the condition of sulphides.

(*i*) Dihydric sulphide (sulphuretted hydrogen) and other soluble sulphides precipitate from non-acid solutions of iron a black sulphide of iron (ferrous sulphide), but in solutions of ferric salts only sulphur is thrown out of combination.

(*j*) When the black ferrous sulphide just alluded to is acted on by a persalt of iron, bisulphide of iron is produced, having the composition of pyrites.

(*k*) Sulphides of iron exposed to the action of air and moisture oxidise with the production of soluble sulphates, and these when moist or in solution oxidise and throw down precipitates of yellowish subsulphate and of yellowish or reddish hydrated ferric oxide.

Processes in constant operation in nature readily bring about reactions such as the foregoing, and the results are accompanied by great changes in colour.

Iron pyrites (bisulphide of iron) in contact with air and moisture oxidises and dissolves, and the soluble sulphates of iron permeating a soil or rock, give to it by further oxidation a yellow, reddish, or brownish colour. Specimens of decomposing pyrites exhibit all these tints, and if the pyrites is burnt there is left a residue of reddish ferric oxide. Changes due to oxidation of pyrites may be noted in streams running from many collieries or pyrites mines, in which there will be found yellow and reddish deposits, due to the oxidation of sulphate of iron, which was itself the product of the oxidation of pyrites. A similar solution of iron sulphates meeting in the course of its percolation through strata compounds of the alkalies or alkaline earths, would deposit their iron in similarly coloured conditions to those just mentioned. The deposition of ferric oxide around the constituent particles of a rock would tend not only to colour it but to bind the mass together, and, in regard to this, it is certain that in the red and yellow sandstones of this neighbourhood ferric oxide is one of the cementing materials.

There is another oxide of iron, intermediate as regards its oxidation between ferrous and ferric oxide—the magnetic oxide—which is often found as a colouring matter. This gives a darker stain, and many of the small black patches of the sandstones in this locality are coloured by it; although some of these, as I showed some years ago with reference to some of the sandstones at Flaybrick, have black oxide of manganese also as a colouring constituent.* Probably very much of the

See "Geology around Liverpool," by G. H. Morton.

oxide of iron that now colours rock masses was originally derived from pyrites by oxidation.

Whilst describing the results of the decomposition of pyrites, it may be well to note also circumstances that may bring about the formation of iron sulphides. The reactions *h*, *i*, and *j* here come into play. Organic matters deoxidise peroxide of iron, and also reduce the sulphates present in decaying organic matter, or in soils or rocks to sulphides, and the sulphides acting on the iron form proto-sulphide of iron; but this meeting with a persalt of iron (and many natural circumstances may be adduced to shew the possible presence of the two together), loses half of its combined iron and a compound having the composition of pyrites is formed.

Referring to reaction *f*, by the combined action of organic matter and water not only is the colour of ferric oxide changed, but that substance is reduced to an oxide soluble in water containing organic acids or carbonic acid. Thus rain water, plus organic matter, percolating through a rock-mass coloured red or yellow by ferric oxide, may reduce that oxide, render it soluble, and remove it elsewhere, leaving the rock in a more or less decoloured condition.

This reaction may be noted in reference to the formation of deposits of iron ores, for by the removal in solution of the iron distributed through a rock, and its subsequent deposition, owing to oxidation, in fissures or cavities, deposits of ores such as hœmatite may have been produced; or without further oxidation there may have been formed beds of carbonate of iron. With regard to the latter the occurrence of beds of spathose iron ore (carbonate) in the close neighbourhood of coal, as in the coal-fields of Staffordshire and elsewhere, with frequently beds of clay, &c., almost free from iron

intervening, is well worthy of consideration. The organic matter of the coal period during its decomposition has probably reduced and removed the iron persalts in its neighbourhood, leaving strata comparatively free from that metal, but the solutions so formed have deposited their iron as carbonate not far away.

This reaction of ferric oxide and organic matter may be considered in connection with the absence of organic remains in strata strongly impregnated with iron. Sir Wm. Dawson* has suggested that the rarity of fossils in red beds is due to the chemical changes that take place between iron compounds and organic substances. Further, it has been pointed out, in reference to the same reactions, by Dr. T. Sterry Hunt† that the occurrence of graphite in the neighbourhood of hœmatite and other iron deposits suggests the agency of organic matter in their formation.

The removal of iron by the intervention of organic matter may be studied in many road-side ditches, especially in boggy districts. On the water of such ditches may be seen an apparently greasy film, which gradually changes colour and throws off a yellowish or reddish substance which is deposited on the sides and bottom of the ditch, and on the surface of vegetation growing there. The water has usually a distinctly ferruginous taste, and chemical tests show the presence of iron in solution in considerable quantity. It may be seen in many places where vegetation with much decomposition occurs that from the underlying soil there has been removed a large amount of its ferruginous colouring matter. Many sandy soils on heaths and commons are almost white owing to

* "Quarterly Journal Geological Society," vol. v. p. 25.

† "Geological and Chemical Essays," p. 301,

the removal of their iron by the combined influence of organic matter and rain water.

The beautiful tints varying through shades of blue, green, yellow, pink, and red, of the nodules and layers of clay found in the sandstone at Bidston during a recent excursion, and which are to be seen in many other localities, are entirely due to the presence of iron in different conditions of oxidation and hydration, and of course the degree of solution of the colouring matter with other substances will account for further great variety of tint.

The change in colour of many clays from grey or blue to brown or red in burning, is due to change in condition of the iron constituents. Many of the blue clays, and also some of the brown, contain much organic matter, to the action of which the lower state of oxidation of the iron is due, and in burning this is destroyed and the iron fully oxidised.

Many interesting examples of alteration of colour owing to interchange of constituents of iron compounds with other minerals, or of the effect of heat, might be described (see reactions *b* to *e*), but the foregoing will, I trust, be sufficient to indicate that by processes of oxidation and deoxidation, combination and decomposition, removal and deposition, an almost infinite variety in colour and shade may be imparted to rock masses by this one substance, iron.

REPORT OF FIELD MEETING AT BIDSTON HILL,

MAY 15th, 1886.

THE recent construction of a road across Bidston Hill has exposed a continuous section of the Keuper Sandstone, of which the hill is composed.

The party proceeded by way of Flaybrick Hill, where they saw a freshly-opened section of the Upper Bunter overlain by a conglomerate, which Mr. Morton has since pointed out to me is the base of the Keuper. At the foot of Bidston Hill we entered the new road which crosses the hill with a sweeping curve, having its outer side to the south. The broken state of the upper part of the rock was pointed out as being partly due to the action of vegetation, and also probably in part to the passage over it of heavy masses of ice. About half way up the road is crossed obliquely by a N. and S. fault, and the sandstone gives place in the section to beds of grey and yellow marl. A trench for a sewer being open at the time shewed a total thickness of marl, with sandy beds, of about 11 feet. About 30 or 35 yards from the first fault another was visible in the trench, and from this to the end of the section at the western face of the hill it was all sandstone, much fissured and jointed. A bed of clay nodules of various colours, from light bluish grey to a brick red, could be traced for some distance, as well as a few small patches of a greenish colour. Mr. A. Norman Tate says in all these cases the colour is due to the presence of iron.

HENRY C. BEASLEY.

REPORT OF FIELD MEETING AT THURSTASTON AND

WEST KIRBY, JUNE 19th, 1886.

THE members proceeded to the new road cut through Thurstaston Hill, where sections of Upper Bunter are exposed, showing the rock much jointed and fissured. The upper portion showed certain dislocations, masses of sandstone having been moved from their original position, probably owing to pressure by glacial ice.

At the summit of the hill a hard quartzose bed occurs, resembling the base of the Keuper, underlain by beds of soft sandstone.

An east and west fault, 7 feet wide, crosses the south end of Thurstaston Hill, in which are exhibited some singular examples of slickensides. Thin veins of hard rock, varying from $\frac{1}{8}$ to $\frac{3}{8}$ inch in thickness, run parallel with the fault, and bear horizontal striations. Similar "porcellaneous slickensides" are noted in joints close to the old road (now closed) at the foot of the hill, with striations dipping 15° to the east.

"Thor's Stone," an isolated rectangular block of sandstone, considered to be due to surrounding denudation, was visited.

Several gullies in the soft Bunter Sandstone occur on the west side of the hill, having deep rocky sides, gradually sloping towards the base. These owe their origin to the action of springs.

At Grange a fault was examined in a quarry, near the Calday-Grange Grammar School. For description of this fault see p. 247.

Several smaller faults, with perfect examples of slickensides, were noticed on Beacon Hill, West Kirby; and at the side of the road leading to West Kirby Village, the President, Mr. G. H. Morton, F.G.S., called attention to a section there exposed showing the basement beds of the Keuper resting upon the Bunter, the latter being current-bedded.

OSMUND W. JEFFS.

REPORT OF FIELD MEETING AT EASTHAM.

JULY 3rd, 1886.

The party proceeded at once to the shore, just south of the hotel; the hard Pebble-beds, resting on softer beds of red sandstone, which have been referred to the Lower Bunter in the "Geological Survey Map," and the "Geology of the Country around Liverpool," were pointed out. The locality is an interesting one, for a boring in the soft red sandstone to the depth of a few hundred feet would probably show whether it really was the Lower Bunter, or only soft strata interstratified with the Pebble-beds, and possibly some indications of the Coal-measures. The microscopic appearance of the soft sandstone indicates it to belong to the Pebble-beds, but only a single specimen has been examined under the microscope.

A few hundred yards north of the hotel an old quarry was examined, and numerous quartzite and white quartz pebbles were seen, and they continued more or less frequently all along the out-crop of the Pebble-beds to Bromborough Pool, where they became scarce, or altogether absent, and the strata gradually covered by the Boulder-Clay. There is a continuous exposure of the Pebble-beds all along the shore from Eastham Ferry to the Court House, near the Pool, but the dip is only 2° W.N.W., and so slight that it is difficult to obtain, especially when associated with the false bedding. Near the Court House there is an old quarry, walled in and partly filled with water, and the dip so slight that it is probably 2° as on the shore. The little time at our disposal prevented any minute examination, and the occurrence of pebbles is uncertain.

Considering the apparent uniformity in the dip over the area examined, it seems probable that the thickness of the strata exposed may be from 500 to 700 feet, which is fully half the recognised thickness of the sub-division in the district. On the whole it seems probable that the base of the Pebble-beds is actually exposed at Eastham Ferry. If this supposition be correct, it follows that the upper beds are absent, and that the lower beds are faulted against the Upper Bunter, and that there is not a regular succession from one sub-division to the other, as shown on the "Geological Survey Map;" but the time devoted to the examination of the area was quite inadequate to arrive at any satisfactory conclusion. Another excursion, taking the return route, with more time to devote to the subject, would be desirable next summer.

G. H. MORTON.

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*Have read Papers before the Society.
†Contribute annually to the Printing Fund.

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OF THE

Liverpool Geological Society.

SESSION THE TWENTY-NINTH,

1887-8.

EDITED BY W. HEWITT, B.Sc.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

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*Royal Dublin Society.
*Royal Geological Society of Ireland, Dublin.
Royal Society, London.
*Smithsonian Institution, Washington, U.S.
Société Geologique de Belgique, Liege.
*Société Geologique du Nord, Lille.
*Société Impériale des Naturalistes de Moscow.
*Société Royale Malacologique de Belgique.
*Sociedade de Geografia de Lisbon.
*Toscana Societa di Scienza Naturali.
*University Library, Cambridge.
University College, Bangor.
,, ,, Liverpool.
*Warwickshire Natural History and Archæological Society.
Watford Natural History Society.
*Wagner Free Institute of Science, Philadelphia.
*Woodwardian Museum, Cambridge.
Yorkshire Geological and Polytechnic Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION TWENTY-NINTH.

OCTOBER 11TH, 1887.

THE PRESIDENT, G. H. MORTON, F.G.S., in the Chair.

Mr. J. TUNSTALL and Mr. A. H. KNIGHT, F.C.S., were elected Ordinary Members.

The Officers and Council for the ensuing year were elected. The Treasurer submitted his Statement of Accounts.

The President then read his Annual Address :—

LOCAL HISTORICAL, POST-GLACIAL, AND PRE-GLACIAL GEOLOGY.

NOVEMBER 8TH, 1887.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

Dr. CHAS. CALLAWAY, F.G.S., was elected an Honorary Member, and Rev. S. GASKING, B.A., an Ordinary Member.

The following paper was read :—

A THEORY TO ACCOUNT FOR THE AIRLESS AND WATERLESS CONDITION OF THE MOON.

By Rev. F. F. GRENSTED, M.A.

GEOLOGICAL AND PHYSICAL NOTES ON ABOVE PAPER.

By T. MELLARD READE, C.E., F.G.S.

DECEMBER 13TH, 1887.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

Mr. D. DAVIES was elected an Ordinary Member.

The following papers were read :—

RECENT DEPOSITS OF THE STANLOW, INCE, AND FRODSHAM MARSHES.

By G. H. MORTON, F.G.S.

NOTES ON GLACIAL DEPOSITS AND MARKINGS IN THE SOUTH OF THE ISLE OF MAN.

By W. HEWITT, B.Sc.

JANUARY 10TH, 1888.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

An Extraordinary Meeting was held, followed by an Ordinary Meeting.

The following paper was read :—

SOME NOTES ON THE GEOLOGY OF ST. DAVID'S, PEMBROKESHIRE.

By T. MELLARD READE, C.E., F.G.S.

FEBRUARY 14TH, 1888.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

Rev. F. F. GRENSTED, M.A., was elected an Ordinary Member.

The following paper was read :—

FURTHER NOTES ON THE PRESTON DOCKS EXCAVATIONS.

By E. DICKSON.

Reports on Field Meetings at Birkenhead, Wallasey, Runcorn, Hilbre, and St. Helens were read.

MARCH 13TH, 1888.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

The following papers were read:—

NOTES ON A LARGE BOULDER DISCOVERED IN OXFORD ROAD, MANCHESTER.

By T. MELLARD READE, C.E., F.G.S.

ON SOME PHYSICAL CHANGES IN THE EARTH'S CRUST.

By C. RICKETTS, M.D., F.G.S.

APRIL 10TH, 1888.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

Prof. JOHN J. STEVENSON was elected a Foreign Corresponding Member.

The following papers were read:—

EXAMINATION OF QUARTZITES FROM NILLS HILL, PONTESBURY.

By P. HOLLAND, F.C.S., and E. DICKSON.

ON THE COLOURING MATTER OF THE MINERAL "BLUE JOHN."

By A. NORMAN TATE, F.C.S., F.G.S.

ON SOME IRREGULARLY SLICKENSIDED JOINTS AT LANGDALE QUARRY, BIRKENHEAD.

By H. C. BEASLEY.

[President's Address.]

LOCAL HISTORICAL, POST-GLACIAL AND PRE-GLACIAL GEOLOGY.

By G. H. Morton, F.G.S., F.R.G.S.I.

Since I read my Address last year another Session of the Society has passed away, and the printed "Proceedings" have been distributed to the members and about seventy societies in this and other countries.

During the recess we have lost by death Mr. Robert Bostock, who, though seldom seen at our meetings of late years, took a lively interest in local geology, and whose genial disposition and shrewd observations will long be remembered by those who knew him.

It may be regretted that the list of members shows a decrease in number, though it is gratifying to find some new contributors of Papers at our Meetings. The last Session was rather remarkable for the variety in the subjects brought forward, than for those on local geology. There were, however, several Papers which cannot fail to be valuable to future observers.

In March last, Mr. H. C. Beasley, during an excursion to Wallasey, pointed out a very clear example of the local breaking-up of a bed of shale, near the base of the Keuper, and its deposition as a brecciated bed, while the underlying basement-bed presented a confused stratum of coarse sand and pebbles, characteristic of its

position. Mr. A. Strahan, F.G.S., has recorded a somewhat similar bed as a "Line of large lumps of shale apparently remnants of a broken-up shale-bed," near the base of the Keuper at Helsby Hill.* No doubt you are all familiar with the frequent lumps and patches of shale, so common in the lower beds of the Keuper around Liverpool, and it is interesting to have discovered that they belong to that formation and were not derived from any earlier one.

Attention has recently been directed to what appears to be the most interesting instance recorded in this locality of *terminal curvature,* or the contortion of the weathered sandstone and an underlying thin bed of shale, by glacial action, in McFall's quarry, in the Lower Pebble-beds at Bankfield Road, West Derby. It has been exposed for several years, but only recorded in an account of a visit by the Geological Association in July last.† The depth of the shale is usually 2 or 3 feet, and it is puckered up, in some places to the surface, while the overlying rubble is compressed and turned over, presenting the appearance that an iceberg might produce when it grounded and was forced by currents over the surface of the weathered sandstone. The section is well exposed along two sides of the quarry, and a wall is built so close to the edge that it may remain open for examination for some years. In the same account reference is made to the well-known quarry at Club Moor, where a similar contortion was supposed to occur. In that quarry the top of the sandstone has certainly a contorted appearance, but is probably only an example of false bedding so much weathered as to present a folded aspect.

* "Geol. of Chester," p. 7.

† "Trans. L'pool Geol. Assoc.," vol. vii., p. 75.

In 1886, Mr. T. Mellard Reade, F.G.S., gave a short account of "A Contorted Section of the Trias at Vyrnwy Street, Everton," * showing evidence of lateral pressure. From the author's description it seems to me to be a similar section to that at Bankfield Road, and to have resulted from the action of ice under the same conditions, a conclusion confirmed by the drawing with which the paper is so clearly illustrated.

Last year, Mr. Wm. Hewitt, B.Sc., our Honorary Secretary, read a paper entitled "Notes on the Topography of Liverpool," † and it was illustrated by a relief model of the area over which the city is built, and which he had constructed himself. The model showed the high ground of Everton and Edge Hill, with the rounded character of the surface as it descends to the river, but varied by some flat areas, which tend to render the average gradient more gradual than it would otherwise have been. Mr. Robert Chambers in his "Ancient Sea Margins," refers to the occurrence of terraces which marked the successive levels of the sea, but his opinion has not been confirmed, and little attention directed to the subject. If in addition to Mr. Hewitt's model we could have another showing the contour of the ground on which Liverpool now stands, as it appeared 200, or even 100 years ago, we should be surprised at the alteration that has taken place during the last century or two, and for the most part during the last only. If, again, we could have another model of the country as it existed just before the beginning of the Glacial period, a far more wonderful change would be apparent. The country around Liverpool at that time must have been a hilly country, with a flora somewhat different, and a fauna

* "Proc. L'pool Geol. Soc.," vol. v., p. 158.

† "Proc. L'pool Geol. Soc.," vol. v., p 145.

remarkable for the presence of many mammalian species, now unknown in Britain, and indicating a milder climate. Recent researches in North Wales, only 20 miles from Liverpool, tend to show that primitive man, with his stone implements, inhabited this part of the country in Pre-glacial times.

HISTORICAL GEOLOGY.

Some of the old prints showing views of Liverpool, at various dates, represent the background, which now forms the higher portion of the city, as a succession or cluster of hills, one behind another, and they seem so conspicuous as to suggest that they only existed in the imagination of the artist and never had any reality. But, on further consideration, it seems probable that some of these views give an accurate perspective outline of the high ground behind the old town, with Everton as the highest point. Ever since Liverpool became an important and rising town, there has been a constant tendency to remove inconvenient ridges and to fill up depressions. Numerous quarries have been worked and the excavations since filled up, built over, and for the most part forgotten; but the sandstone obtained was only used for public buildings and such parts of other erections as rendered the use of stone desirable. The houses and ordinary buildings have always been built of bricks, obtained from the boulder-clay, which covers the low ground between the ridges of rock running from north to south. Consequently brick making has ever been in progress, and a waste margin of brick-fields constantly receding before the extending boundary of new streets and houses. Brick-fields existed in Whitechapel, Byrom Street, and Old Hall Street so recently as 1766, but they are now just beyond the 2-mile radius. The general

tendency of the removal of the clay has been to lower the surface, though much of the clay taken off has been replaced by various kinds of *débris*.

The filling up of the Old Pool, from which Liverpool derives its name, was one of the earliest operations tending to level the ground, but it is unnecessary to do more than refer to what is so well known, The Pool must have resembled Bromborough, Tranmere and Wallasey Pools, as they were 40 or 50 years ago, and they were all tidal pools with muddy banks inland. Liver Pool took its rise on the flat land below Windsor and Edge Hill, and the flood-gates on the site of the present School for the Deaf and Dumb, at the top of Oxford Street, were placed where the water was collected in a regular channel. I remember, about 1839, a wide ditch along the east of Grove Street, between Falkner and Myrtle Streets, and an arch-way under Oxford Street just above Grove Street, which may have represented one of the old lines of drainage. In 1875, in the railway cutting under Chatham Street and Peach Street, I saw a thick bed of black mud, indicating the definite course of the Pool. From those streets it originally crossed Brownlow Hill by the bottom of Ashton Street, across Daulby Street, London Road and Stafford Street, to Byrom Street, where it turned to the south near Scotland Place, between Circus Street and Richmond Row, and became a tidal pool along Byrom Street, Whitechapel, and Paradise Street, when it opened out where the present Custom House now stands. The last mention of the Pool in the "Records of Liverpool" * was in 1721, when it was ordered "That gravel be laid on the common shore (now Paradise Street) to make the way passable from Lord Street to the Glass House," which then stood

* "Gore's Directory."

at the bottom of Argyle Street. In Chadwick's Map, 1725, the site of the Pool about Paradise Street was laid out for streets, though no houses had been erected; but in Eyes's Map, 1765, the area is represented as covered with buildings. The Lodge of the old Botanic Gardens on the site of the flood-gates, and now that of the School for the Deaf and Dumb, still remained in 1840, though the new gardens in Edge Lane had just been opened. From Brownlow Hill to Parliament Street was mostly waste land and had evidently been a peat-bog—indeed some peat remained; but the surface was usually a soft peaty soil, evidently the decomposed base of the bog from which the peat had been taken off. I frequently dug through the peaty bed, some 2 or 3 feet, into the Upper Drift Sand beneath, but after digging to that depth further progress was hindered by the infiltration of water discoloured by the peat. I never saw the remains of trees in the peaty soil, neither did I find any shells in the underlying sand. Along the east side of Crown Street there were brick-fields, and during the construction of the South Haymarket, at the top of Oxford Street, since removed, some fine sections were exposed showing the Upper Drift Sand, about six feet thick, resting on the Boulder-Clay beneath.

The area occupied by the peaty bed would have been far too damp for the erection of houses over it, and an excavation of a few feet was immediately filled with water; so that to utilise the land it became necessary to form the streets at a higher level. When this was done, by means of stones and rubbish, the streets were from one to 12 feet above the original surface. Before any houses were built they resembled railway embankments, and the highest, about St. Saviour's Church, must have been 12 or 15 feet above the peat; while towards Crown Street,

Parliament Street, and Hope Street they gradually joined the rising ground. The whole of the area between Edge Hill and Hope Street, or between the Upper Pebble-beds on the east and the Keuper on the west, forms a hollow containing boulder-clay and sand, but with the surface so low, that a peat bog was formed and must have existed for hundreds if not thousands of years.

The appearance of Hope Street, as depicted in Herdman's "Pictorial Relics of Ancient Liverpool," gives some idea of the great changes that have taken place there. The windmill was on, or just to the west of Hope Street, and the still higher ground shown in the view represents the spot on which the Philharmonic Hall was built in 1846. The site of the building was originally 20 feet above the level of Hope Street, and sandstone was removed to that extent before the excavation for the foundation was made. I remember a high wall forming the south of Myrtle Street and the east of Hope Street, and the field inside ascended considerably above the top of the wall. The opposite, or west side of Hope Street, seemed to have been an old quarry, and for many years it was used as a Corporation stone-yard; but on the north of the quarry along Hardman Street just below a corner house, since taken down, the land was 15 to 20 feet above the street, against which was a mural exposure of the rock with a north and south fault crossing it. Between Hope Street and Pilgrim Street the land rose from the quarry and was as high as Hope Street, so that the houses in Rodney Street must have been built on what was formerly a rapidly descending surface.

Proceeding southwards, the rock about St. James' Cemetery has been lowered, and a windmill formerly stood on, or about, the site of the chapel at the north-

west corner, and at a rather higher elevation.* The rock has been levelled since the mill was removed, but the quarry *débris* forming St. James' Mount is higher than the original rock. To the east of the Cemetery, about Upper Parliament Street, the Greek Church, and along the whole of the east side of Berkley Street, the rock has been lowered to the depth of from 7 to 10 feet. St. Patrick's Chapel, in Park Road, stands upon the original surface, but the rock has been taken off to the depth of 10 or 15 feet along the east of Park Road, as far up as High Park Street, and beyond that to a less extent. About Grafton Street and the Midland Railway Station, there have been quarries along the high ground and much of the rock removed.

Returning to Hope Street, the ground at the top of Mount Pleasant, about University College, has been lowered several feet; and Mr. F. P. Marrat informed me that the rock, to the extent of 20 feet, has been taken off the surface about Gill Street and Great Newton Street, where the ground was of a mound-like form and quarries worked. I remember some houses at the bottom of Pembroke Place, on the south side, which were some 10 feet above the road, and indicated the rise of the surface referred to. Edge Hill Church probably stands on nearly the original surface, but a cutting now exposed at the top of Paddington shows that the rock has been cut away to form the road, and some houses with small gardens formerly stood on the south side 9 or 10 feet above it. In 1836 there was a deep quarry on the east side of Edge Hill Church, and the present condition of the houses built over it indicates the subsidence of the *débris* with which the quarry was filled up. Paddington

* Herdman's "Pict. Rel. of Anc. L'pool," 1878, plate xxviii.

was formerly very steep towards Edge Hill, and the central portion, between Smithdown Lane and Mason Street, was filled up about 1846, so as to obtain the present more gradual incline. The site of Mount Vernon Hall has been lowered six feet during the last few months, and the Post-office at the top of Prescot Street stands on ground which was recently 10 feet higher than now. The ground on the west of Hall Lane has been lowered, and that a little to the west of Low Hill must have had about 15 feet of the surface of the rock removed towards Chapel Place, and so recently as 1845 a rocky bank surmounted with a hedge ran up the south side of Brunswick Road.

There were formerly quarries in front of the College in Shaw Street, the site of St. Augustine's Church was higher than now, and between it and Everton Road much of the rock at the surface has been removed since 1850 and several feet of sandstone taken off large areas between Everton Village and the church. Everton Church may be on the original surface, which is now 241 feet above ordnance datum, but probably the rock was levelled when the church was built. In the old prints Everton is always represented as the highest ground behind the town, and of a rounded form. Between Everton Church and Kirkdale, the surface has in many places been lowered, and in others filled up so as to obtain a more gradual descent.

Along the centre of the town from north to south, the boulder-clay usually covers the Upper Bunter sandstone, and the tendency has been to raise the surface, and especially the lowest part along the course of the old Pool. William Brown Street, formerly Shaw's Brow, was originally much steeper, and much of the rock has been removed about the north of St. George's Hall. The middle portion of Scotland Road has to a great extent

been excavated through the Keuper sandstone, which was originally 20 feet above the site of the market. About the same thickness of sandstone has been removed along Stanley Road, between Merton and Balliol Roads, and that height of rock is now exposed at the back of the houses on the east side of Stanley Road. Very great alterations in the level of the roads have been made in the same neighbourhood during the last 20 years, and an enormous amount of rock and clay removed for railway lines and to accommodate the gradients to them. I need only mention the fringe of docks, which has been entirely reclaimed from the river. The line of roads just inside the margin of the docks represents, as near as possible, the old shore as it existed 200 years ago.

The removal of the mounds and ridges of rock, and the filling up of depressions in the surface, constantly in progress for so many years, have produced a very remarkable change in the contour of the ground on which Liverpool is built, and explain the absence of that variety of outline so conspicuous in the old views of the town, which were mostly taken from the Mersey. The cluster of hills just behind the old town was formed by the undulating surface of the Keuper sandstone, while the more regular outline of the background was the Bunter sandstone, thus confirming the general correctness of the views. A fine series of maps and views of Liverpool in the Free Public Library, enabled me to compare and study the drawings produced by many artists who lived during successive years. The band of Keuper sandstone, running across the town from north to south and about half-a-mile in width, formerly presented a constantly varying surface and must have formed an attractive border outside the town; but the levelling and quarrying described have destroyed the beautiful rocky aspect that

it once possessed, as proved by descriptions and drawings made during the last 100 years. If an inhabitant of old Liverpool could return, he would not be able to recognise a single surface feature that he was familiar with 200 years ago.

As the covering of boulder-clay is usually absent from the ridges of sandstone, but fills up the intervening valleys to a considerable thickness, it is obvious that if the whole of the clay were removed, the country would present a more hilly character than it does, for as the valleys would be deeper, the hills would appear relatively higher than they do now. The thickness of the boulder-clay seldom exceeds 150 feet, but it is usually much less, and in many places on the high ground only a few feet, or absent altogether. It does not seem that the clay was ever much thicker, or that it filled up the low land to a much greater depth than it does at present. The general contour of the country is nearly the same now as it was just after the emergence at the close of the Glacial period, the most conspicuous denudation since that time being along the boulder-clay cliffs, which occur at intervals along the banks of the estuary of the Mersey, and so exposed to marine action. If the surface of the boulder-clay had been much denuded, beds of boulders and pebbles would have been left behind, after the clay had been re-deposited, or carried away to the sea. No doubt the blue silt in the Post-glacial deposits was derived from the boulder-clay, but the denudation in the valley of the Mersey would supply the amount of clay required.

One hundred years ago the pavements as well as the middle of the streets were paved with pebbles and boulders, and they were far too numerous to have been collected from the shore, the brick-fields, or from any bed

of rounded stones lying on the boulder-clay; and there are no such beds likely to have afforded the quantity required. The first flags in the town were used about 1790 in covering the pavement of a terrace long afterwards known as Islington Flags, but the pebbles were common in side streets in 1840. I remember a large house in Mount Pleasant, nearly opposite the Wellington Rooms, that had the pavement in front constructed with small egg-shaped stones, forming a star with an ornamental border. Many of the stones were quartz, which could not have been easily obtained from the boulder-clay. I think that both pebbles and boulders were brought to Liverpool as ballast, and that they were afterwards taken up and broken to pieces for the roads. Macadam was introduced about 1827 for the middle of the streets, but the large boulders which formed the channel-stones were only replaced by the present granite curbs in London Road so late as 1858.

POST-GLACIAL GEOLOGY.

An examination of the shores of the Mersey shows the surface of the rock to be naturally low, and to be buried under a thick covering of boulder-clay. The strike of the Bunter sandstone is about north and south, and this has no doubt originally determined the direction of the valley from some former geological period. There are a few exposures of rock such as at New Brighton, the Dingle, Rock Ferry, Garston, Eastham, Ince, and other places, but they are seldom much elevated, and the inference is that they have not extended far into the river in Post-glacial times. In a few places the coast is bounded by cliffs of boulder-clay, sometimes 30 or 40 feet high, but this elevation is very exceptional, for the land usually slopes towards the estuary, and leads to the conclusion

that a low and wide valley existed between what are now Lancashire and Cheshire ever since the elevation of the country, about the end of the Glacial period. A large portion, probably two-thirds of the coast-line, between Weston Point and the mouth of the Mersey, is either low banks of boulder-clay, embankments, or walls to protect the country from the encroachments of the sea, and many square miles would soon be added to the influence of the tides if conservative measures were relaxed. For a very long period the sea appears to have been encroaching on the land, and consequently the boulder-clay cliffs have been receding, and such historical accounts as we happen to possess confirm the waste of the coast-line, which is well known to every local geologist to have taken place. The Frodsham, Ince, and Stanlow Marshes, and a few smaller areas have been more or less reclaimed, besides about 5 square miles of docks, but otherwise there has been a constant widening of the Mersey. It would not be difficult to obtain the estimated average waste of the boulder-clay along the coast for many years back; but the amount of land lost, that I have myself seen on the Cheshire shore, has in some years been so great as to be obviously of exceptional intensity. The denudation opposite Liverpool has evidently been increased by the building of the docks, and probably the average would not be so great as supposed, though the estuary must have become somewhat wider in recent years.

Although the large area of docks and piers has been reclaimed from the estuary, about 6 miles in length, it appears to have been land at some former time, for, except at the south end of Liverpool, it covers a long space formerly occupied by the Submarine Forest-bed in front of the town. This old land surface existed under

the site of the Albert Dock, under the Custom House, and continued below the more northern docks and then along the shore to Bootle and Formby.

Much has been written on the origin, form, and supposed outlets of the Mersey—far more than I can even mention—but I feel compelled to refer to what seems to have been the first of a long series of recent papers and discussions on the subject, and I need not trouble you with the remarks of Ormerod and other early writers on the Mersey.

In the "Pictorial Relics of Ancient Liverpool," 1844, Mr. W. G. Herdman wrote the following:—"South of the present Liverpool the reader must imagine a large inland lake of great beauty and extent, the mere of the Saxon period, surrounded by gentle eminences crowned with ancient woods, and having an outlet to the sea by the present Wallasey Pool, but spreading wider and shallower between Bidston and Wallasey, over what is now Bidston Marsh, and entering the sea by the present Wallasey embankment, but more seaward and altogether unnavigable." The author collected together for the first time a great deal of information which has since appeared in more recent papers, though many of his statements, including that quoted, are not entertained. In the later edition, 1878, the geological paragraphs have been eliminated. Mr. Herdman's work was omitted in my "List of Papers on the Geology of the Country around Liverpool," and the literature of the subject is incomplete without it.

About five years later, in 1849, Mr., now Sir James Picton, read a more comprehensive paper, entitled: "Changes of Level of Sea and Land on part of the West Coast of Britain during the Historical Period, or Encroachments of the Sea in the neighbourhood of

Liverpool," in which he showed, most conclusively, that the Mersey could not have flowed to the sea through Wallasey Pool. In the same paper the author observed that:—"Had the estuary of the Mersey always presented the copious body of water which it does at the present day, it would be difficult to account for the neglect which it met with from the Romans, who were generally so judicious in their selection of stations." "Roman stations existed at Chester on the Dee, at Ribchester on the Ribble, and at Lancaster on the Lune, but the Mersey, the most considerable and navigable stream in the country, seems to have been utterly neglected; unknown we cannot conceive it to have been;" and again he said: "We are therefore irresistibly driven to one of two conclusions—either that the Romans displayed in reference to the Mersey an apathy, or ignorance, which attaches to them in no other instance, or that the estuary of the Mersey *in its present form* did not then exist."*

That the Mersey was not specially mentioned by any Roman writer has been accepted by Mr. Joseph Boult † and others who have referred to the subject. The oldest known so-called "Ptolemy Maps" were copied or compiled in the 15th century, and they differ considerably from each other. One of these Maps dated 1455 shows the Dee, the Mersey, and even "Lerpoull," and is evidently of about that date. ‡ In the various editions of Ptolemy's Geography, a large portion is little more than a list of places, but with latitudes and longitudes. Recently (1877–9) Mr. T. G. Rylands, F.S.A., considers that he has shown that the Belisama of the Romans is

* "Proc. Lit. & Phil. Soc." (Abstract), vol. v., p. 113. Privately printed *in extenso*. (Quotation from newspaper copy.)

† "Proc. Lit. & Phil. Soc.," vol. xxvii., p. 249.

‡ "Trans. Hist. Soc. Lan. & Ches.," 3rd Ser., vol. vii., plate vi.

the Mersey, and not the Ribble, as hitherto supposed.* Liverpool is situated in N. latitude 53° 23′, W. longitude 2° 54′. Ptolemy† gives Belisama Æstuarium as in N. latitude $57\frac{1}{3}$° and E. longitude $17\frac{1}{2}$°, and he gives the Seteia Æstuarium as N. 57° and E. 17°, so that corrections are necessary in order to find the true positions of places. Mr. Rylands assumes that he has succeeded in interpreting Ptolemy's method of tabulation so as to construct a chart of the coast line from Carnarvon to Cumberland, proving the Belisama to be the Mersey as known to the Romans. If this result be confirmed it is of great interest, but it does not give us any information as to the condition of the river or estuary in Roman times. Still more recently Mr. W. Thompson Watkin in his "Roman Lancashire," published in 1883, admits the correctness of Mr. Ryland's conclusions, and says that he thinks that "the Belisama and Seteia are the Mersey and Dee respectively," but this does not lessen the force of Sir James Picton's observations on the estuary.

The Mersey has attracted the attention of many other writers, and the late Mr. Robert Bostock read a paper entitled "The Mersey and Dee—their former Channels and Changes of Level,"‡ in which there is an able criticism on several opinions that have been expressed on the subject. Mr. C. E. de Rance, F.G.S., in the "Superficial Geology of South-West Lancashire," has fully described the Post and Pre-glacial deposits. Mr. T. Mellard Reade, F.G.S., in several well-known and valuable papers published in our "Proceedings,"§ has collected a large number of sections and borings relating

* "Trans. Hist. Soc. Lan. & Ches.," 3rd Ser., vol. vii., p. 83.

† "Clavdii Ptole" (1535), p. 36, in Free Public Library.

‡ "Proc. L'pool Geol. Soc.," vol. ii., p. 41.

§ "Proc. L'pool Geol. Soc.," vols. ii., iii., iv., and v.

to both the Post and Pre-glacial course of the Mersey. Fortunately he was able and willing to collect data, which would otherwise have been lost, tending to show the ancient course of the river and that it entered the sea by its present mouth.

In "The Geology of the Country around Liverpool" there is a clear distinction made between the Mersey as a river and as an estuary, and it seems absurd to suppose that the river was unknown to the Romans, and I still hold the opinion I did in 1863, that the estuary of the Mersey is a comparatively recent arm of the sea and may have only assumed its present form and importance since the Roman occupation.

Assuming that the Mersey was a valley and not an estuary in former Post-glacial times, it is quite certain that there must always have been a wide river flowing down the centre, which after receiving many tributary streams along its course, fell into the sea somewhere about its present mouth. It is obvious that such a river, flowing over 20 miles of flat country, would wind about and cause swamps and marshes, with floods when heavy rains filled the main stream and its tributaries. This was probably the normal condition of the river, especially when we consider the clear evidences of subsidence afforded by the Submarine Forests, which have been so often described, and occur on both sides and along the southern border and eastern termination of the estuary. It is quite unnecessary for me to describe these old Forest-beds, for you must all be familiar with them and the great depth at which they often occur below ordnance datum. The Forest-bed under the site of the Albert Dock has never been described; but I well remember the late Mr. Francis Archer, about 1845, informing me that he had just been to see it, and that he had seen a

quantity of hazel nuts and an old dagger that had been found over it.

In 1858 * I visited the Submarine Forest-bed at the mouth of Wallasey Pool, with my friend Mr. T. J. Moore, and we saw a number of the stumps of trees from 2 to 4 feet above the ground, and obtained the splendid skull with the horns attached of *Bos primigenius* now in the Free Public Museum. There cannot be any doubt that the trees had grown on the bed where we saw them. There was a bed of overlying blue silt, and then a quantity of sand, which formed the bed of the pool, across which I remember walking from Birkenhead to Seacombe in 1845. The Forest-bed could not by any process have slipped from a higher level, and the trees must have been in the places where they grew, when the land was at a greater elevation and the Mersey flowed down the centre of the valley into the sea, with a border of forest land on each side of it.

Such was the assumed condition of the river Mersey, until some undefined period, when a subsidence began, and as a natural consequence the sea to encroach on the land. Probably the subsidence was very slow, or it may have been by a series of slight downward movements; but as it went on, the tides would gradually back up the inland water and cause floods. As the years rolled on, the spring tides would force their way further and further up the valley, while the retreating water would widen the old river bed and produce a tidal stream, and in the course of time the estuary of the Mersey, with its remarkable lateral pools, as it was 200 years ago. It is probable that the subsidence of the land and the gradual encroachment of the sea, extended over so many centuries, that

* "Geol. of L'pool," p. 47, and "Trans. Hist. Soc. of Lan. and Ches.," vol. x., p. —

the changes suggested would attract little or no attention in such a remote part of the country. The advance of the sea would cause the projecting headlands of boulder-clay to be denuded at the base and steep escarpments to be formed at occasional intervals on both sides of the Mersey; while the sea would be still gradually invading the upper end of the valley and flooding the country, until the subsidence ceased and a state of equilibrium was reached.

These are geological conclusions, and quite independent of the meagre historical information we possess; but I venture to suggest that the subsidence was in progress in Roman and Saxon times, and that it could not have ended much before the 14th century. The encroachment of the sea had not ended in 1279, when "there was a dreadful inundation" at Stanlow Monastery, between Ellesmere Port and Ince, as recorded in the "Chronicle of St. Werburgh." In 1289 the Abbey lands again suffered from an inundation, so that the monks in 1294 removed to Whalley. The Abbey was built on the rock about 1178, and no doubt upon a site considered at the time to be perfectly safe. So far as the building was concerned, it might have remained until now, though a high tide, under certain conditions of the wind, would possibly have reached the foundation, in the absence of the embankment which now protects the land. Little now remains of the Abbey, only some thick foundation walls, ancient doorways, and excavated passages in the rock, and an old farm house covers the original site. Stanlow is on the Pebble-beds, and the Abbey was about two hundred yards from the point which projects into the Mersey. The rock, of very limited area, is surrounded by many feet of brown silt, which has a marsh on the top and the original surface of the land beneath. The

principal portions of the Abbey lands seem to have been along the coast, and are now covered by the waters of the estuary. So recently as 1750 a large area (120 acres) is reported to have been swept away by the sea,* and many acres in recent years.

Little need be said about the Post-glacial beds, which occur on both sides of the Mersey. The beds of blue silt over the old Forest-bed were the natural result of the subsidence, and when they had accumulated above the reach of the ordinary tides, beds of peat were formed on which in some instances trees grew. Marsh grass grows at the level of a 15-feet tide. In the "Geology of the Country around Liverpool" there is no allusion to any elevation of the land, which seems unnecessary to account for the recent beds of peat. The lowest old Forest-bed represents the original surface of the country before there was any subsidence, and it now varies in depth just as the old surface varied in elevation above the former level of the sea.

Forty years ago, I collected numerous mammalian bones, horns, and teeth from the Leasowe Post-glacial beds, and very similar remains have been more recently obtained by Mr. Reade from the same strata about Formby, but nothing has been found of any great antiquity, except those of the bear. In 1871 Mr. Reade gave a section at Bewsey Valley, Warrington, where the skull and bones of a bear were found on the old Forest-bed which rested on a bed of gravel just over the rock, and in 1876 Mr. Moore and I discovered a skull of the same animal at the Atlantic Docks, that had just been found at the base of a thick bed of blue silt, resting on the boulder-clay from which the old Forest-bed had been

* Hanshall's "Hist. of Ches.," p. 615.

denuded. From the appearance of the skull, which had lost the lower jaw and some teeth, it seemed to have been exposed some time before it was embedded in the silt, or had been derived from an older bed.

LIST OF THE MAMMALIAN REMAINS, RECORDED FROM ALL THE LOCALITIES ABOUT THE MERSEY.

Man.	Living.
Bear.	Extinct in 10th Century.
Dog.	Living.
Ox, *Bos primigenius.*	Extinct.
,, ,, *longifrons.*	?
,, ,, *taurus*	Living.
Sheep.	Do.
Red Deer.	Do.
Pig.	Do.
Horse.	Do.
Whale.	Do.

This list does not help us much in deciding the age of the Post-glacial beds. *Bos primigenius* from Wallasey Pool and the Bear from the North Docks seem to be the only extinct species and occur in the lowest beds, but all the others are of a very recent character. All the remains seem to be derivative and not directly deposited in the beds in which they were found. It is remarkable that the Wolf, the Fox, and the Wild Boar are not in the list, and altogether the beds seem to be of very recent origin.

There is a difficulty with regard to the flint and bone implements, the Roman and Saxon antiquities, and other articles, including coins of various times down to the Victorian age. The flint implements might have been used at the time of the Romans, or even after. The antiquities have been found almost entirely at Leasowe,

about Dove Point, by the late Dr. Hume and others,* not on the lowest Forest-bed, but on the upper Forest-bed, and in the silt just over it. They tend to show that the Post-glacial beds of Leasowe are of greater antiquity than hitherto supposed, but information is required as to the conditions under which they were deposited before they enable us to decide on the precise age of the beds.

The estuary of the Dee contains a great deposit of boulder-clay, and coal-seams have been worked under it for many years. It presents evidences of subsidence very similar to the Mersey, for it has a bordering Forest-bed, several miles in length, along its north-eastern margin, and marshes on the opposite coast. The Dee has been silting up from long before the Roman occupation, but no description of the river has come down to us from that period. Mr. William Shone, F.G.S., says that a tract of land, about a mile in width, and about 6 miles in length, between Hilbre Island and Heswall, and formed of boulder-clay, has been swept away in comparatively recent times. †

The Vale of Clwyd presents a thick deposit of boulder-clay, but the underlying Bunter sandstone is exposed in many places. The River Clwyd is a stream that winds about as it flows down the Vale, and the Elwy falls into it about 3 miles from the sea. About the mouth of the Clwyd there is an old Forest-bed with an overlying bed of silt and peat, indicating a subsidence of the coast in Post-glacial times. Prof. T. McKenny Hughes, F.G.S., in "Notes on the Geology of the Vale of Clwyd," gives two sections of the strata, but they do not show the lowest Forest-bed. ‡

* "Ancient Meols, or Antiquities found near Dove Point, on the Sea-Coast of Cheshire."

† "Proc. Ches. Soc. of Nat. Science," part iii., p. 52.

‡ "Proc. Ches. Soc. of Nat. Science," part iii., p. 36.

PRE-GLACIAL GEOLOGY.

Geologists have long been of opinion that the general form and contour of the land of Great Britain was much the same before the Glacial period as it is now, and there can be no doubt that the valleys of the Mersey, the Dee, and the Clwyd are very similar to what they were before the cold period began. During the later submergence, the country became covered with drift, which has since been more or less denuded. The hills have been slightly lowered by subaerial agency and the hand of man, but the three valleys referred to must have long existed in their present form. What the elevation of the land was with regard to the sea before the Glacial period began, it is impossible to ascertain with any certainty, but we seem compelled to admit that the surrounding country was, during the latter portion of the time, submerged to the depth of many hundred feet, and after a short interval again elevated to about its original position. A subsidence and elevation of such magnitude seems improbable, but there is no other satisfactory explanation of the occurrence of shells in the drift at great elevations. It would, however, be very extraordinary, if after the emergence of the land, it permanently rested at precisely its former level with regard to the sea, and as there are many reasons against it having been lower, the inference is that the Pre-glacial surface was a little higher than it is at present. By the term Pre-glacial, I mean the time just before the Glacial period began, and not the previous geological periods which might be considered Pre-glacial.

It may be safely assumed that in this district and over the whole of the country around the valleys of the Mersey, the Dee, and the Clwyd, the denudation during

several geological periods has been of enormous extent. There can be no doubt whatever that in addition to the Keuper sandstone and much of the Bunter formation, there must have been at least one or two thousand feet of the Red Marl denuded from off South-west Lancashire and Cheshire. Most geologists assume that the Lias and Oolite, and some even Cretaceous strata, once covered the country, and have since been denuded. It would be too theoretical to attempt to trace the history of these rivers to their origin, and I could add little, or nothing, to what has already been written on the subject, especially relating to the broad valleys where they empty themselves into the sea.

Prof. Ramsay, in his "Physical History of the Dee,"* speaks of it as a river with "a history compared with which those of the Thames, the Rhine, the Ganges, and most of the great rivers of the modern world are matters of yesterday." He says that, like the Mersey, it is Pre-glacial from where it leaves the hills and all down its estuary, but the upper portion is "a river of very ancient date," which must have once flowed 1300 or 1400 feet higher over the surface of formations long since denuded. It is uncertain where its ancient mouth was situated, but its present outlet between the Coal-measures and the Trias probably began in Liassic or Oolitic times.

Prof. Ramsay describes the Clwyd as not only Pre-glacial, but as dating back so far as to present "a Permian or pre-Permian Clwyd,"† which flowed down the old valley with the Carboniferous Limestone and Wenlock shale on both sides. The river seems to have been lost during the deposition of the Trias and other

* "Geol. of North Wales," p. 314.

† "Geol. of North Wales," p. 306.

later formations, but it appeared again not later than the Eocene, or earlier than Oolitic times. Submerged in the Glacial period, it has since resumed its course again, but not in its unknown ancient channel, which is buried in the drift.

The estuary of the Mersey runs entirely through Triassic strata, and is not of such ancient date as the Dee or the Clwyd. At its mouth it conforms to the strike of the strata, but crosses it where it becomes wider, and expands to the south-east. After the Glacial emergence, the Mersey resumed its ancient course, where it enters the sea. According to Mr. Reade's papers, there may be some considerable difference in the upper reaches of the river, compared with its course in Pre-glacial times, and I consider it quite possible that it may have entered the sea in a different place at some still earlier period. Rivers, however, excavate their channels much quicker than the rain and frost can wear away the sides of the valleys along which they run; and there does not seem any strong reason for supposing that the Mersey ever ran into the sea at any other place than its present mouth. Wallasey must have been an island twice—whether for a day, or a century, we cannot expect ever to know; but if it were so for only a few years, it would be a sufficient time for marine action to assist in the excavation of the remarkable valley between the Mersey and Leasowe, and which has given rise to the opinion that the river once flowed through it to the sea.

The origin of the Mersey was certainly after the Triassic and most probably in the Oolitic period, and although it must always have flowed between the Coal-measures bounding the Trias on the north and the south, it may have changed its course in ancient geological times; but as it then flowed to the sea over

a land surface 1,000 or 2,000 feet above the present, it is useless to speculate on the features of a country of which we cannot know anything.

The surface of the country in Flintshire and the Vale of Clwyd is covered with a drift deposit very similar to that around Liverpool. It occurs up to an elevation of 500 feet, but above that its former presence is indicated by patches of red clay in the hollows of the rock and by a few small stones and boulders on the surface. The estuaries of the Mersey and the Dee and the Vale of Clwyd all contain a thick deposit of boulder clay, with associated sand and gravel; but while the sea covers the surface of the clay in the two first, the latter is so much higher that it presents a flat country, with a river winding down to the sea, resembling the old valley of the Mersey in Pre-historic times.

If we could clear off the drift from these three great valleys and from the surrounding country, and elevate the whole 100 or 200 feet, we should see something of the rocky grandeur presented in Pre-glacial times. Our own Triassic area must then have been a country with alternating sandstone ridges and deep valleys, more rugged than it is now, half buried in drift. The contour of the Post-glacial surface of the rocks, before it was levelled by human agency, does not favour the theory of a great sheet of glacial ice moving across the country, for it would have tended to reduce the land to a comparatively flat surface, with undulations rather than abrupt ridges of sandstone.

The denudation of the country during the Mesozoic and Cainozoic periods has been so great that no trace of any formation remains of later age than the Red Marl. The surface of the rocks is uncovered by any recent for-

mation, older than the Glacial drift. No older river gravel or lacustrine deposit has been recorded in the country bordering the three valleys so frequently referred to. "The sand and gravel with pebbles of copper and lead-ore, and horns, teeth and bones," of the elephant and stag, found below the surface at the Talargoch Mine, first described by Dr. Buckland, are Glacial beds, * the contents having been derived from the Pre-glacial surface. If any such early deposits had been preserved, we should have probably found traces of the extinct mammalia discovered in the caves on both sides of the Vale of Clwyd, but as there are no such remains in any local deposit either in Denbighshire, Flintshire, or South-west Lancashire, it proves the great antiquity of the Cave fauna. There are no marine Pre-glacial deposits along the neighbouring sea-coast, but of course they are not likely to occur if the land is now lower than it was in Pre-glacial times. In the bed of the Mersey, during the construction of the tunnel, the deposit above the rock was found to be boulder-clay, with numerous boulders at the base. Mr. Reade saw a hard boulder-clay on the rock, but the dangerous conditions under which the bed was worked did not allow any constant geological examination to be made. As it seems certain that there are no Pre-glacial deposits within the area described, we have to rely entirely on the deposits preserved in the Caves of the Vale of Clwyd, for any knowledge of the mammalian fauna that lived in the country in Pre-glacial times.

The Glacial period may be assumed to have been introduced by the gradual cooling of the climate towards the end of the Pliocene period. There can be no doubt

* "Geol. of Rhyl, &c.," p. 29.

that the high land of North Wales and the north of England, with Scotland, became covered with glacial ice; but we have been unable to ascertain the condition of the intervening country. The Vale of Clwyd being the nearest to the icy land, may have been covered, but there is no certainty about it; and with regard to the valleys of the Dee and the Mersey, with all due respect to the opinions of others, I have not been able to find any satisfactory evidence that the country was invaded by the ice. That it may have been annually covered with a thick bed of snow, which melted each summer, seems probable enough; but that glacial-ice ever flowed down or across the valleys is unsupported by the kind of evidence we might reasonably expect. When, however, the later period of subsidence began, the country would be submerged beneath the sea, over which icebergs and ice-fields are supposed to have floated, or stranded according to the depth of the water at the beginning and ending of the submergence. Unfortunately we know nothing of the rate of the subsidence, the time it lasted, or the rate of emergence, but we do know that the country was covered with a mantle of boulder-clay and sand, containing erratic blocks, mostly from northern sources, during the period that the land had been under water. We, however, find the surface of the rock often striated by ice, and sometimes showing terminal curvature, but these are only occasional exceptions to the usually weathered surface, and I attribute them all to drifting ice.

Connected with the Pre-glacial period are the Caves of Denbighshire, with their interesting mammalian fauna. It is not my intention to take up your time with any minute description of them, for they have been so recently brought prominently forward, as presenting the most reliable evidence of the Pre-glacial age of man. At

the Cae-gwyn Cave,* the one most recently examined, a bed of undisturbed boulder-clay was found to overlie the entrance in such a position as to seal up its contents. During ten days I was at the cave last summer with Dr. Henry Hicks, F.R.S., I had ample opportunity of becoming familiar with all the details, both inside and outside of this and the Ffynnon Beuno Cave, which is only a few yards distant.

While I was at the cave it was visited by many geologists, and the opinion expressed was almost unanimous as to its Pre-glacial fauna. It does not seem that the position of the boulder-clay at the Cae-gwyn Cave in relation to the sand and bone-earth beneath can be doubted; but before accepting evidence of such importance, it was deemed advisable that the ground outside the entrance should be still more thoroughly examined, so that it might be seen that no other explanation of the facts was possible. This final examination has been made during the last few weeks, and the result is the confirmation of Dr. Hicks's original conclusions.

LIST OF THE MAMMALIAN REMAINS FOUND IN THE FFYNNON BEUNO AND CAE-GWYN CAVES.

Lion.	Long extinct.
Wild Cat.	Living.
Spotted Hyæna.	Long extinct.
Wolf.	Extinct in England 1500, Scotland 1700.
Fox.	Living.
Bear.	Extinct in 10th Century.
Badger.	Living.
Wild Boar.	Extinct above 200 years.

* "Rep. Brit. Assoc.," "Jour. Geol. Soc.," "Proc. Geol. Assoc.," and "Geol. Mag."

Ox (? as to species).	?
Great Irish Deer.	Extinct.
Red Deer.	Living.
Roebuck.	Living.
Reindeer.	Living in Arctic regions.
Horse.	Living.
Woolly Rhinoceros.	Long extinct.
Mammoth.	Long extinct.

It has been doubted whether the animals, many of whose remains occur in the cave and are now living in the country, could possibly go so far back as Pre-glacial times, especially as there is an absence of some southern species that might have been expected to occur; but it now seems probable that the animals that frequented them had not such an ancient facies as was supposed. The remains found prove that the Lion, Spotted Hyæna, Bear, Irish Deer, Reindeer, Woolly Rhinoceros, Mammoth, Elephant, and the Hippopotamus lived in Denbighshire in Pre-glacial times, the two latter having been found in the Cefn Caves. The finding of a flint flake in the bone-earth, beneath the boulder-clay, just outside the entrance of the Cae-gwyn Cave, proves that man inhabited the district with the extinct and other mammalia. It does not seem possible that all the species could have remained in North Wales after the cold began, and there is no evidence of any Inter-glacial period during which they could have returned after they had once migrated southwards to a warmer latitude. It seems very improbable that the Lion, Hyæna, Rhinoceros, Elephant, and Reindeer ever existed in the neighbourhood in Post-glacial times, for there is not a vestige of their remains in such deposits.

The result of a careful examination of the Cae-gwyn Cvae, extending over two years, proves that it was fre

quented by the mammals referred to and by man in Preglacial times. When the cold of the Glacial period began to be felt, the animals migrated to the south, leaving the cave containing the bones and teeth of a long line of ancestors, which were gradually covered by a thick bed of stalagmite from 12 to 14 inches in thickness. The bone-earth represents the Pre-glacial period, and the bed of stalagmite the cold period when North Wales was glaciated and uninhabited. Then came the period of submergence, when the land subsided, and for some time the mouth of the cave was subjected to the force of the waves from the advancing sea, which broke up the thick stalagmitic floor along its narrow chambers and recesses, disturbed the bone-earth, and drove the bones and teeth before it, so that they were not only found in the bone-earth, but forced into hollows and cavities at the sides, and some even outside the mouth of the cave. The fragments of the stalagmite were found mixed up with the bone-earth, there being small pieces and large blocks in a confused mass; but just above there was a thin seam of laminated clay, evidently the result of quiet deposition, and then a bed of sand reaching to the roof of the cave. Outside the entrance to the cave, the bone-earth, the laminated clay, and sand extended several feet, with an overlying bed of gravel which reached higher than the entrance, and above all was a solid bed of boulder-clay some seven feet in thickness.

It appears certain that the mammalian remains in other caves in the Vale of Clwyd are of the same Preglacial age, and were disturbed from their original positions by the action of the sea, under the same conditions as at Cae-gwyn and Ffynnon Beuno, at the beginning of the glacial subsidence. Professor Boyd Dawkins objects to the Pont-Newydd Caves being Pre-

glacial, on the ground that stone implements were found in them made from rock which occurs as boulders in the drift in the neighbourhood; but it seems quite as probable that man may have obtained the stone from its original locality, or from moraines in the early period before the district was covered by ice, as it to have been brought in the form of boulders. Most of the caves have had the drift deposits about them washed away in Post-glacial times, and many since invaded by animals still living or not long extinct in the country. Some have been occupied by man in recent times, but there seems to be no difficulty in determining the Pre-glacial deposits in them.

In conclusion, you will imagine that I had some difficulty in finding a suitable title to the chain of facts and conclusions that have been brought before you. It appeared most convenient to go backward in time, from the known to the comparatively unknown, and so reverse the order in which geological information is usually conveyed; but that course is by no means original. True facts are for ever valuable, and I trust that some of those recorded may be found useful hereafter. Theories are built up with the facts we possess at the time, and go on changing as our knowledge increases; and this is especially evident in the science we cultivate. In speculating on the Origin of the Mersey, Post-glacial times, the Great-submergence, and Pre-glacial times, much is left to "the scientific use of the imagination"; but the finding of true facts must in the end lead to the truth.

A THEORY TO ACCOUNT FOR THE AIRLESS AND WATERLESS CONDITION OF THE MOON.

By Rev. F. F. Grensted, M.A.

(Communicated by T. Mellard Reade, C.E., F.G.S.)

It seems to be usual now-a-days to assume that in the present airless and waterless condition of the moon we see a state of things that the earth is one day destined to come to. It is thought that, at some period in the distant past, the moon passed through a stage with air, water, and possibly life, such as the earth has now; but that by some process, the like of which our own habitation is undergoing, she lost the air and water she once had.

The basis of this reasoning seems to be as follows. We find in the solar system that, roughly speaking, the order of magnitude is the order of temperature. The sun is the largest, it is also the hottest. Jupiter, a typical large planet of low density, very likely still partially shines by its own light—in other words, may be yet red hot within its dense cloudy wrappings, that never permit the real surface to be seen. The earth still has active volcanoes, and has a temperature that rises some 1°F. for each 60 feet of penetration into the interior, clearly pointing to a previous epoch when she was hotter than at the present time. She is three-quarters covered by sea, whilst Mars, only one-tenth the size, is only one-quarter so covered, yet otherwise in cloud, rain, and snow is the counterpart of the earth. The moon, $\frac{1}{80}$ the weight of the earth, has no air and no water, but there is plentiful evidence of former volcanic action, now extinct. Every other body in the heavens too, so far as we can observe, obeys the same law of the connection of

magnitude and temperature. Radiation is constantly causing these bodies to lose a portion of their heat, and we know no way in which the waste can be supplied. Now it is obvious that if we imagine these bodies to have once been all equally intensely heated, the smaller would have become cold first. This is what we find, and we are therefore prompted to look to the present condition of the smaller bodies as representing what the earth will be in the future, and to that of the larger as representing what it was in the past. Such is the usual idea; but on the other hand there is a fundamental difference between the observed condition of the surface of the moon and that of the earth, which seems to show that she never had water on her surface, and so, by analogy, air; her mountains are nowhere in lines or ranges; they are everywhere scattered profusely and irregularly over her surface, and are evidently volcanic in their nature, with here and there an intervening darker bare plain. Mr. Mellard Reade, in his work "The Origin of Mountain Ranges," connects the upheaval of mountain ranges with sedimentary deposition, seeking to shew that great sedimentary deposits have everywhere been followed by the upheaval of mountain ranges, and that where the deposit has been absent the range has been absent. If this be admitted, it must follow that as the moon possesses no ranges she has no sedimentary deposits—that is, she never had water for them to be deposited in, nor air to carry the vapour which would be condensed as rain and wash away the surface.

It is the object of my paper to shew how this may well have been the case, even if we assume the earth and moon to be two precisely similar masses of matter, perhaps once united together in a single nebulous or fluid mass.

Now we know nothing as to the composition of the interior of the earth. If we assume it to be identical in composition with the outer crust, as we usually do, it is a pure hypothesis, and, I seek to shew, an unwarrantable one.

We do know, however, that the mean density of the earth is 5½ times that of water. We also know that the outer crust is almost entirely composed of oxides of a comparatively light density; about 2½ times that of water.

The percentage chemical composition of the crust is thus estimated by Roscoe :—

	Per cent.		Per cent.
Oxygen	44 to 48·7	Calcium	6·6 to 0·9
Silicon	22·8 — 36·2	Magnesium	2·7 — 0·1
Aluminium	9·9 — 6·1	Sodium	2·4 — 2·5
Iron	9 9 — 2·4	Potassium	1 7 — 3 1

And we further know that none of the oxides have a density of 5½, as is well shewn in the following comparative table of the densities of metals, and of compounds mostly oxidised:—

Platinum	21·50	Barium Sulphate	4·70
Gold	19 23	Ruby, Garnet, Opal	4·00
Lead	11·37	Lithographic Stone	2·68
Copper	8·95	Fluor Spar	3·17
Iron	7·79	Marble	2·80
Zinc	6·91	Flint-Quartz	2·65
Magnesium	1·74	Selenite-Gypsum	2·30
Calcium	1·57	Basalt	2·94
Sodium	·97	Granite	2·69
Potassium	·86	Porphyry	2·78
		Serpentine	2·57
		Slate	2·77

Here we observe that most of the metals (in the left hand column) have a density of over 5½, whereas the majority of the oxides are below 3; quartz, the commonest, being 2·65. Hence either the solid material of the earth's interior is compressed into nearly one-half its normal

volume, or it is not composed of oxidised material. I submit that the latter is by far the more probable. I cannot imagine, for example, that a solid crystal of quartz could be compressed into nearly half its bulk; and again, a consideration of the densities of the different heavenly bodies leads to the same conclusion. They are as follows :—

	Masses. (Earth's, = 1.)	Densities. (Earth's, = 1.)	Densitiés. (Water, = 1.)
Sun	315000	0·2552	1·444
Jupiter................	301	0·2435	1·378
Saturn	90	0·1325	0·750
Neptune	26	0·204	1·15
Uranus	15	0·226	1·28
Earth	1	1·000	5·66
Venus	0·9	0·850	4·81
Mars	0·1	0·708	4·01
Mercury	0·0625	1·21	6·85
Moon	0·0125	0·579	3·28

Now in this list there is no connection apparent between density and size; that is, the density is not due to compression by gravity. Mercury, $\frac{1}{16}$ the earth's mass, has a greater density than the earth; Mars, $\frac{1}{10}$, has a density of $\frac{7}{10}$, and the moon, $\frac{1}{80}$, has a density of nearly $\frac{6}{10}$ that of the earth.

I submit, on the other hand, that it is probable that the vapours of many of the metallic elements would condense to a fluid state at a temperature above the temperature of dissociation—that is, before they could become oxidised—in which case they would form a nucleus for the future earth of probably pure metal. As the temperature slowly fell this mass would only become oxidised *on the outside* when the temperature made this possible, and thus would be formed a superficial oxidised crust analogous to the slag floating on the surface of the

molten iron in an iron furnace. This slag would then, as it does on a small scale in an iron furnace, protect the interior from further oxidation. We may thus form an idea of the distribution of matter in the earth, the interior would be chiefly made up of pure metallic iron, if we may draw an analogy from the prominence of the iron lines in the solar spectrum; and on this would be deposited layers of compounds in the order of their condensation. I believe it is probable that there is a layer of sulphurization below the layer of oxidation, for this reason: sulphur is less volatile than oxygen. At a sufficiently high temperature sulphur would probably expel oxygen, for the same reason that lime expels ammonia from combination with an acid—ammonia, though strong, being volatile, while lime, though weak, is not.

There are a few considerations which, though not connected with the main line of argument, yet tend to confirm the foregoing.

(1.) Meteoric stones are often wholly metallic, usually mainly iron. Here at least we have bodies with a metallic nucleus—the only heavenly bodies, too, whose interior we can examine. Whether or no a recent conjecture be credible, that at an early date they were thrown from the earth, and simply for mathematical reasons return to the very point from which they started, or in other words, their meteoric orbits must of necessity intersect that of the earth, the analogy of their constitution with that of the earth is at least probable.

(2.) The meteorite of Lenarto consists of iron containing 2·85 vols. of hydrogen; under ordinary pressure iron when heated absorbs only about 0·5 vols. of hydrogen, hence it would seem that this meteorite was formed under great pressure in the presence of hydrogen.

(3.) The earth is a great magnet.

(4.) Sulphur is mostly found in and near volcanoes.

* Free hydrogen gas is evolved from volcanoes to a small extent, together with such gases as sulphuretted hydrogen and sulphur dioxide. If a volcano be formed by water coming in contact with the matter rising from the heated interior, this is what we should expect. Water is decomposed by iron and other metals at a red heat, evolving hydrogen according to the equation

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2.$$

Water also probably reacts with sulphides evolving H_2S and SO_2, and these gases again combine to form sulphur and water.

Thus by volcanoes we can learn something of the inside of our earth, and it corroborates what we have before regarded as probable by *à priori* reasoning.

We will next proceed to calculate the thickness of the oxidised crust of the earth on the assumption that the mean density of the earth is $5\frac{1}{2}$ times that of water; that of the crust $2\frac{1}{2}$, and that the nucleus has a density of $7\frac{3}{4}$, being composed mainly of iron, and that compression by gravity and expansion by heat balance one another.

Although exactness is impossible, we shall in this way gain an idea of the sort of numbers we have to deal with.

Let r_1 = earth's radius.

r_2 = radius of iron nucleus.

Then the volume of the oxidised crust will be $\frac{4}{3}\pi(r_1^3 - r_2^3)$,

,, ,, iron nucleus ,, $\frac{4}{3}\pi r_2^3$.

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* At Santorin, in the great eruption of 1886, fissures in the lava before the eruption yielded gases consisting of—CO_2 78·44: N_2 17·55: O_2 3·37. During the eruption the result was—CO_2 50·41: H_2 16·12: CH_4 2·95. After the eruption the result was—CO_2 90·78: O_2 0·88: N_2 8·34. During the eruption stifling odours of HCl and SO_2 were recognised, and at a little distance H_2S was disengaged in large quantity. —Ansted's "Physical Geography," p. 324, Ed. 1871. See also A. Geikie's "Text Book of Geology," pp. 201-235; Judd's "Volcanoes," pp. 40 and 213; Prestwich's "Chemical and Physical Geology," p. 205.

And knowing the densities we obtain the equation:—

$$\tfrac{4}{3}\pi r_1^3 \times 5\tfrac{1}{2} = \tfrac{4}{3}\pi (r_1^3 - r_2^3) \times 2\tfrac{1}{2} + \tfrac{4}{3}\pi r_2^3 \times 7\tfrac{3}{4}$$

$$\therefore 5\tfrac{1}{2} r_1^3 = 2\tfrac{1}{2} r_2^3 - 2\tfrac{1}{2} r_1^3 + 7\tfrac{3}{4} r_2^3$$

$$\therefore 3 r_1^3 = 5\tfrac{1}{4} r_2^3$$

$$\therefore r_2 = \sqrt[3]{\frac{3}{5\frac{1}{4}} (4000)^3}$$

$$\therefore r_2 = 3319$$

$$\therefore r_1 - r_2 = 4000 - 3319 = 681 \text{ miles.}$$

That is, on the above assumptions only *about one sixth* of the depth from the earth's surface to its centre is oxidised crust. If, however, we regard the moon as a body formed on the same type as the earth, that is with a metallic nucleus of density $7\frac{3}{4}$ and an oxidised crust of density $2\frac{1}{2}$, knowing from astronomical data the mean density to be $3\frac{1}{4}$, we can in the same way compute the probable thickness of this crust, the moon's radius being 1000 miles. In the same manner as for the earth we obtain an equation:—

$$3\tfrac{1}{4} r_1^3 = 7\tfrac{3}{4} r^3 + 2\tfrac{1}{2} r_1^3 - 2\tfrac{1}{2} r_2^3$$

$$\therefore r_1^3 = 7 r_2^3$$

$$\therefore r_2 = 522 \text{ and } r_1 - r_2 = 478 \text{ miles.}$$

Next follows the main point of my theory. If it be true that both moon and earth have a metallic nucleus with an oxidised crust, why has the one air and water, the other not? It is simply a question of *size*. The moon has a larger surface than the earth in proportion to her bulk, and therefore more of her mass was oxidised. The air and water were *chemically*, not *mechanically* absorbed, when her surface was above a red heat. It needed a greater proportion of slag to protect the metallic nucleus; the oxygen, &c., which would have made air and water was thus used up: we, on the other hand, have free oxygen left. I proceed to develope this idea with more mathematical exactness. If the diameter of

the earth be 1, that of the moon is 0·2729, hence her volume is about $\frac{1}{50}$ and her surface $\frac{1}{13}$ of that of the earth. But for simplicity let us take the diameter of the earth as 1, that of the moon as $\frac{1}{4}$. Then her volume would be $\frac{1}{64}$ and her surface $\frac{1}{16}$; that is, she would have four times as much surface in proportion to her bulk as the earth has. If all things were truly proportional, this would simply mean that the oxidised crust of the moon is $\frac{1}{4}$ the thickness of that of the earth. But the extent of the oxidation of a cooling globe depends on the amount of surface, not on the volume. The tendency of the oxidation is to penetrate to the same depth in all cases alike; the moon therefore must have in this way used up a greater proportion of oxygen than the earth has, as the oxidation has proceeded to a greater *proportional,* though possibly to a less *actual* depth.

If my calculations as above in any way represent the truth, we find the earth has an oxidised crust of 681 miles thick. If all were truly proportional that of the moon should be about 170 miles thick, while that resulting from calculation shews 478 miles—a greater proportional though a less actual depth—pointing to a greater chemical consumption of oxygen, &c., and further pointing to the probability of the moon consisting to a larger extent than the earth of oxygen; a very natural thing when we remember that she is, on Dr. G. Darwin's hypothesis, simply $\frac{1}{80}$ of the original mass which broke away from the remaining $\frac{79}{80}$ths, and therefore naturally would consist mostly of outside material having the least density.

I shall next roughly calculate what addition to the thickness of an oxidised and compound crust of light density, the absorption of the earth's atmosphere and ocean would make. It is astonishingly small. Assume

all the oxygen in the air and water of the globe to be converted into Ferric Oxide Fe_2O_3. Of what thickness would be the shell of iron used up; that is, to what depth would this affect a metallic nucleus? The pressure of the air is 15 lbs. per square inch, of which $\frac{1}{5}$ is oxygen and $\frac{4}{5}$ nitrogen; equalling a pressure of 3 lbs. oxygen and 12 lbs. nitrogen per square inch.

We will next assume that the amount of water on the globe is equivalent to a uniform ocean two miles deep; then since 1 cubic foot of water weighs about 1000 oz., the pressure per square inch would be—

$$\frac{1760 \times 2 \times 3 \times 12 \times 1000}{1728 \times 16} = \text{about } 4584 \text{ lbs. per sq. in.}$$

Of this $\frac{1}{9}$ is hydrogen and $\frac{8}{9}$ oxygen; that is, $4074\frac{2}{3}$ lbs. oxygen and $509\frac{1}{3}$ lbs. hydrogen.

Let us imagine this oxygen converted into Fe_2O_3 and see what weight and thickness of iron will be required.

Fe = 56. O = 16. ∴ 48 pts. oxygen combine with 112 pts. iron.

∴ $4074\frac{2}{3}$ lbs. oxygen combine with $9507\frac{5}{9}$ lbs. iron.

But the density of iron is 7·79, and 1 cubic ft. water weighs 1000 oz.

∴ A rod of iron 1 sq. inch section weighing 7790 oz. is 1728 in. long.

∴ A rod of iron 1 sq. inch section weighing $9507\frac{5}{9}$ lbs. is $\frac{48 \times 9507\frac{5}{9} \times 16}{7790}$ yards long.

That is about 937 yards, representing the thickness or vertical depth of the shell.

In like manner the oxidation power of the oxygen of the atmosphere where the pressure is 3 lbs. to the square inch, is $\frac{48 \times 3 \times 16}{7790} = \frac{2304}{7790}$

That is, less than half a yard in depth.

Hence just over half a mile in depth of extra oxidation of an iron nucleus would use up all our oxygen.

The earth's crust we know, to an enormous depth, say 30 miles—and I have shewn by calculation very probably to some hundred miles—is oxidised to an extent of some 44 to 48 per cent. Add to that thickness less than 1000 yards, which on the smallest assumption is less than one-fiftieth its present known amount, and all our oxygen both from air and ocean are gone. What a miserable residue, after all, our atmosphere and ocean must be! It is not so easy to see what would become of the hydrogen and nitrogen, but after all there is comparatively little of them, only 12 lbs. per square inch of nitrogen and $509\frac{1}{8}$ lbs. of hydrogen, as against $4074\frac{3}{8}$ lbs. of oxygen. The hydrogen may well have gone in some such way as that of which the hydrogen in the meteorite of Lenarto gives us an example, being (so to speak) dissolved in the metallic interior. The nitrogen may have entered into combination as nitrides; for example, of Boron, such as probably gives rise to the Ammonium Borate of the Tuscan lakes, itself a volcanic product, and the source of the volcanic ammonia of commerce. The equation $BN + 3H_2O = B(OH)_3 + NH_3$ would explain this.

Or the well-known Titanium Nitrides, which are formed at high temperatures. Or again, which is more to the point, it may be combined with Silicon, as happens when it is heated strongly with it. Silicon itself may exist unoxidised in the earth's interior, especially as at high temperatures it to a certain extent dissolves in metals, such as Aluminium, Magnesium, Zinc, and probably others. And further, we must not forget that hydrogen is found, together with nitrogen in smaller quantities, amongst the gases evolved during a volcanic eruption.

The theory which is now before you in its complete form also gives a satisfactory explanation of another strange lunar phenomenon, which is described in the following extract from Guillemin's "Heavens":—

"There are seen to start from two principal points, "Tycho and Copernicus, two series of luminous rays, "which traversing the mountains and neighbouring fea-"tures, extend to a great distance from these brilliant "centres. Aristarchus, Kepler, the Carpathians and "many other centres present analogous systems "which appear to converge, intermingle and connect "themselves together. These singular appearances, of "which no entirely satisfactory explanation has yet been "given, are only visible about the time of the full moon. "They disappear at the other phases, and this seems to "shew that they are not due to elevations, as then they "would cast shadows, and on that account be clearly "visible."

In other words, they behave exactly like a reflecting surface opposite a light: for example, a window reflecting the setting sun.

Why may not these streaks, considering the necessary thinness of the oxidised crust, be *dykes of pure metal*, which have a bright surface untarnished by any oxidising air or water?

In conclusion, I may say that I do not propound this theory as one which, in our present state of knowledge, we can look upon as anything but a speculation: but I consider that it shews on how slight a foundation rests the assumption that our attendant orb reveals to us a stage to which our own earth must necessarily one day come, or that the moon ever resembled, with atmosphere and ocean, the world on which we live.

GEOLOGICAL AND PHYSICAL NOTES.

By T. Mellard Reade, C.E., F.G.S., &c.

It is frequently assumed by physicists and chemists that the oxidation of the materials of the earth is still going on, and that the earth will finally arrive at the airless and waterless condition seen on the moon. It appears to me that this is an assumption opposed to geological fact. Geology, if it shews anything, tells us that in the earliest ages in which life occurred, the conditions of atmosphere and water cannot have been greatly different from those of the present time.

But these early ages were many millions of years ago, even by the admission of those that are most parsimonious of geological time. If water is still being used up in hydrating the minerals of the earth, it follows that in former ages the bulk of sea water was much greater than now. This means for the early ages, such as the Cambrian, less land and deeper seas. There is no geological evidence of any such conditions prevailing then. Many physicists who adopt the "Contraction" theory of the earth, tell us, on the contrary, that the seas have been gradually deepening since early geological times. Such mutually destructive physical beliefs as are embodied in these propositions tell strongly in favour of uniformity of conditions through long ages. We may also ask ourselves if oxygen has been continuously abstracted from the atmosphere since the dawn of geological time, what was its composition in, say, the Cambrian age? Was the oxygen then greatly in excess? or, if not, what has become of the nitrogen? I venture to think that such speculations carry their own refutation and land us in absurdity.

I think we must therefore accept the conditions of practical permanence of air and water on the earth now; by means of organic reactions a balance of conditions seems to have been attained from a very early age.

We are very ignorant of what may be called stellar chemistry, and speculations as to how the present state of things first came about can, in the present state of knowledge, be little more than guesses at truth.

Mr. Grensted, in his suggestive paper, brings forward clearly the importance of relative magnitude in the differentiation of planetary conditions. He shows that the moon has, in round figures, four times the surface area as compared to her mass that the earth's surface has compared to its mass. It follows that if the nucleus of both planets is unoxidised metal, and the crust or outer shell consists of oxidised minerals, the moon would use up more oxygen, relatively speaking, in her crust than was used up in the crust of the earth. It seems to me, though we may not be able to trace out all the processes, that these conditions must necessarily be productive of considerable surface differences in the two planets.

Be that as it may, the evidence seems to me conclusive that the moon has never possessed the surface conditions we see now on the earth. There are no signs of subaerial denudation, which is one of the great agents of geological change on the earth. She is covered all over with volcanic phenomena, using the term "volcanic" in its widest sense. Had the large rings and craters so prominent on the moon been subjected to the surface conditions of the earth, they would have been largely destroyed, and their materials worked up into sedimentary deposits. The surface features of the moon are, in respect to mountain ranges, entirely unlike those of the earth.

There is another differentiating effect caused by the lesser bulk of the moon. Lunar gravity at the surface is not more than one-sixth that of the earth. If then the earth is, as most physicists suppose, solid from the centre to the surface by pressure, the moon, unsubjected to so great a pressure, may have consisted of an outer hard crust and a fluid nucleus. This appears to me a condition likely to bring about the surface features we see so plainly through the telescope, and which have been so admirably portrayed in Nasmyth and Carpenter's book. The welling up of the fluid mass and congelation round the edges, and its after sinking, may have produced the large rings and sunken pits. This condition of hard crust and fluid nucleus, if it ever existed in the moon, has at all events not been productive of the ridgings up and foldings, which, on the "Contraction" theory of the origin of mountain-ranges, should be more pronounced on the moon than on the earth. For the evidence of such foldings we search in vain. The moon's surface, though covered with immense volcanic rings, exhibits no distortions in them which can be attributed to tangential pressure.

This appendix, however, is hardly the place to work out the consequences that flow from these considerations. Suffice it to say, that Mr. Grensted has pointed out that the chemistry of a planet's surface may be profoundly influenced by magnitude.

In designing structures such as large bridges or ships, all practical engineers know that one great element to be considered is actual size. In theorising on stellar conditions and the dynamical geology involved, no less must relative magnitude form one of the main factors in the solution of such problems.

STANLOW, INCE, AND FRODSHAM MARSHES.

By G. H. Morton, F.G.S.

The south coast of the estuary of the Mersey, between Ellesmere Port and the River Weaver, is bounded by a marsh, which is divided at Ince by a promontory of the Lower Pebble-beds, and there is an outlier of the same rock at Stanlow Point. Stanlow Marsh extends from Ellesmere Port to near Ince Hall, and the sandstone at Stanlow Abbey is surrounded on the land side by the marsh. From the Lighthouse at Ince the marsh extends to Holpool Gutter, beyond which as far east as the Weaver is Frodsham Marsh. Outside the embankment along Frodsham Marsh there is a long narrow strip in its natural condition, traversed by numerous channels of water; and though the surface is covered by the tides, a species of grass grows upon it. That grass should grow and flourish where almost daily covered by the salt-water seems remarkable. This fringe of marsh is known as Frodsham Score, and a similar though narrower space occurs outside the embankments of the Ince and Stanlow Marshes.

The elevation of the surface of the marshes varies from 14 to 20 feet, but outside on the scores it is only from 10 to 15 feet above ordnance datum. The surface rises inland, and it seems probable that the land sinks along the edge of the marshes in consequence of the action of water on the bed of sand which is below the estuarine silt and peat. Between the sand and the silt there is a continuous Old Land Surface, or bed of peat. The altitudes on the 6-inch ordnance maps are not given along the coast-line so frequently as necessary to determine the precise elevations of the marshes outside the

embankments, though sufficiently numerous to ensure general accuracy.

The section exposed along the coast from Ellesmere Port to Holpool Gutter shews a nearly continuous bed of silt from 6 to 10 feet in thickness. The Old Land Surface with the remains of trees, in the position in which they grew, is well exposed between Ince Lighthouse and the cliffs in front of Ince Hall. The underlying sand is shewn in a section by Mr. A. Strahan, F.G.S.* That a bed of sand underlies the peat seems well known to residents in the neighbourhood, and it has been proved by borings for the Manchester Canal at Ince Ferry and on Stanlow Marsh, a short distance from the sandstone cliffs at Ince. Though I at first considered it to represent the Upper Drift Sand, I have now a doubt about it, and the borings in connection with the Canal do not afford any satisfactory evidence as to its character. I was informed by the Lighthouse keeper that there are two beds of peat, and he shewed me the supposed lower bed in the mud about 100 yards from the coast, but it seemed the same as the one below the silt which dipped towards the Mersey. He informed me that occasionally the shore was swept bare by the tide, and that the peat beds were then well exposed; but I have always found the shore covered with thin mud, and that it was impossible to venture many yards from the mural bank of silt which presents a steep face towards the river for several miles.

The following is the section of the beds about 100 yards west of the Lighthouse:—

Stratified Estuarine Silt - - -	1 foot.
Brown ,, ,, - - - -	3 feet.
Old Land Surface, with the remains of trees - - - - - - -	1 foot.

* Geology of Prescot, Lancashire, 3rd Edition, p. 31.

Underneath there is white sand, or estuarine sandy silt, which rests on Boulder Clay, or the Lower Bunter Sandstone according to position. Nearer the land, the silt rests on Boulder Clay which reposes on the rock.

In conclusion, I assume that the Old Land Surface shown about Ince Lighthouse represents the cultivated land surface previous to 1294, when the monks of Stanlow Abbey left the district in consequence of the terrible inundations that flooded the surrounding country, as described in the "Chronicle of St. Werburgh." The present surface of the marshes could not have been the original surface as it existed in the 13th century, for there is very clear proof that the estuarine silt has been growing upwards in consequence of the gradual deposition of silt. A general subsidence of the country to the extent of about 10 feet seems to have taken place since the Abbey was founded, but it has been increased over parts of the area by the local sinking of the marshes, especially along the coast line. If I am correct in assuming that the Old Land Surface, now covered with the estuarine silt, was the surface of the country when Stanlow Abbey was erected about 1178, it may easily be imagined what a splendid site the rocky eminence of Stanlow must have been, when it was surrounded by a fertile valley, with the Mersey, then a narrow river, perhaps a mile to the north.

During the approaching summer thousands of navvies will be at work along the line of country described, so that fine sections of the strata will be exposed and much additional information obtained. Under these conditions this communication can only be considered a preliminary introduction to a more full and complete description of the geology of this interesting district.

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* "President's Address," Proc. L'pool Geol. Soc., vol. v., p. 209.

NOTES ON GLACIAL DEPOSITS AND MARKINGS IN THE SOUTH OF THE ISLE OF MAN.

By W. Hewitt, B.Sc.

During a short visit to the south of the Isle of Man, last summer, I had an opportunity of examining the glacial deposits so well displayed in shore sections at Port Erin, Port St. Mary, and in the neighbourhood of Castletown. Some of the points noticed in connection with these sections, especially with regard to the glacial markings, I am induced to bring before the notice of the Society, since they have not, so far as I know, been previously described.

The drift beds of the island were well described by Cumming in a paper "On the Geology of the Isle of Man" (Q. J. Geological Soc., 1846), and also in his "History of the Isle of Man," published two years later. They have since been described by J. Horne, F.G.S., in a paper entitled "A Sketch of the Geology of the Isle of Man" (Trans. Edinburgh Geol. Soc., Vol. II., Part 3, 1874), and by the Rev. J. Clifton Ward, F.G.S., in the Geological Magazine for January, 1880.

The lowest and most striking deposit consists of a yellowish brown clay of a tough character and full of stones, many being of large size. In the number and size of the contained boulders it presents a striking contrast to the Boulder-clay of the Liverpool district. The boulders are mostly sub-angular, having only the edges and angles worn off, and all, or nearly all, are scratched on several faces. For the most part they consist of the rocks in the immediate vicinity, though there is a small

percentage of foreign rocks. Thus in the section at Hango Hill, near Castletown, the majority of the boulders are cuboidal blocks of limestone; at Port St. Mary they are mainly of limestone, but of smaller size, with a few others of grit, red sandstone, granite, &c.; and in both cases the clay rests on thin-bedded Carboniferous Limestone.

This deposit is spoken of by Horne and Ward as *till*, and by both stated to be of ice-sheet origin. As met with at Port St. Mary, resting on the limestone, also near the Travertine Cliff described by Cumming in Poolvash Bay, at Hango Hill, and at the Scarlet limekilns near Castletown, it certainly seems to answer in every important respect to the characteristic till of Scotland, as described by Dr. Jas. Geikie in his "Great Ice Age." That is to say, it is a firm, tough, tenacious clay, homogeneous and altogether unstratified, for the most part of local origin, and with almost every stone contained in it well striated on several faces.

At Port St. Mary, against the breakwater, a good section of stony till from 3 to 8 feet thick is seen resting on a polished and striated bed of limestone, which is rounded and dips towards the sea. The till is capped by a gravelly deposit of rounded pebbles, cemented by carbonate of lime, and this deposit sometimes overhangs the cliff of till, which is evidently subjected to great waste by the action of the sea. The till here abuts against a stepped limestone cliff, which will be again referred to.

Against the limekilns at Port St. Mary there is a remarkably fine section of till 15 to 20 feet thick, which also abuts against the landward face of a stepped limestone cliff. A little further south again, the section at the same horizontal level as the last shows a small

thickness of till overlying the limestone, but rendered very hard and adherent to the limestone by an infiltration of carbonate of lime. The till in this instance looks partly as if it had been sorted out in water, and is overlaid by 12 to 15 feet of clay, in parts very fine leaf clay, with local patches of more or less current bedded gravel. This is again capped by the deposit—here 6 or 8 feet thick—of well-rounded pebbles and small gravel, cemented by carbonate of lime, and which is evidently a raised beach. (The pebbles in this raised beach deposit are mainly of limestone, and this, I presume, is the source of the carbonate of lime which serves as the cementing material.) Still further south we come again to the higher beds of limestone, covered by the usual stony till, with the gravelly deposit above. A similar raised beach deposit described by Cumming, occurs at the head of Poolvash Bay, near Strandhall, overlying a similar bed of till; and, as at Port St. Mary, the latter is washed out, leaving the cemented pebbly deposit overhanging, often to the extent of several feet.

Whenever the junction of the till with the underlying limestone is seen, the latter is found to be polished and well striated. This is well shown at Port St. Mary against the breakwater and to the south of the limekilns, and at Scarlet, near Castletown, in the limestone quarry and on the adjacent shore. As pointed out by Cumming, the striations in these districts are in direction approximately magnetic east and west; according to measurements by Horne, they vary from about W. 27° S. to S. 28° W. Clifton Ward considers the striations may have been caused, not by land ice, but by current floated ice, when the land was somewhat below its present level; but the remarkably well-polished surface, so well shown in a freshly exposed area at the Scarlet Quarry, seems cer-

tainly to have been due to land ice. The occurrence of till immediately over the scratched surface, wherever that is seen, would also lead us to regard the two phenomena as connected in their origin. In all the cases described it should be noted that the striated surfaces are situated from about high water level to a few feet above. In the Scarlet limestone quarry close to the shore, a large area of the upper bed of limestone had recently been exposed in the process of the work. The limestone, which slopes gently to the shore, is overlaid by a deposit of stony till, which thins out as the limestone rises; and a thin bed, consisting largely of small well-rounded stones (not altogether like the bed at Port St. Mary), which capped the till, comes to rest directly on the limestone. Up to the level at which the limestone had been covered by till the surface of the rock was beautifully planed and polished and marked with very distinct striations; but where the limestone had been covered by the gravel there were no signs of polishing or striation, but the surface was worn into numerous elongated deep hollows, like so many widened joints, all filled with a fine earthy deposit. The abrupt termination of the perfect ice marking on the gently sloping surface was very striking. It is not unlikely that the action of water percolating through the gravel has removed the polished surface; whereas, where the rock was covered by the clay, the markings have been perfectly preserved.

At Port St. Mary (as also at Scarlet Point) the beds of Lower Carboniferous Limestone, full of fossils, are from 1 to 3 feet thick, and separated by shale partings. They are thrown into numerous curves, and, especially where they slope towards the sea, they are broken into large tabular masses by the action of the waves and removed, leaving cliffs in the form of a succession of steps. It

would appear that before the till was formed a similar stepped cliff arrangement existed in places on what is now the landward face of the limestone. For example, against the breakwater at Port St. Mary the till abuts against an almost vertical stepped cliff of this kind. The bed of limestone on which the till rests, and which is capped by 4 or 5 higher beds in the cliff, is finely polished and striated down to a line running from the inland edge of the cliff in the general direction of the striæ towards the sea. Again, at the limekilns at Port St. Mary, the upper limestone beds end inland in a succession of six steps, against which abuts a mass of unstratified stony till. Each step is well polished and striated on both its horizontal and exposed vertical sides, the horizontal edges are well rounded off, and striæ may be seen running obliquely from the horizontal to the vertical faces. These steps have a total difference of height of from 5 to 6 feet. Numerous other blocks in situ at different levels are polished and scratched on two sides at right angles in a similar way. It seems to me plain that this kind of action could only be caused by a sheet of land ice which moulded itself exactly to the existing contour of the rock. The erosion of the coast in this locality is very great, and the limestone before the Glacial Period must have extended much further seaward than it does at present. The ice sheet would appear to have travelled almost parallel to the present shore line at this point, in a valley one side of which was formed by this stepped limestone cliff.

I noticed also in this locality that the numerous small projecting bosses on the surface of the bed of limestone were scratched and polished in each case only on the east or north-east face, the striæ diverging somewhat as they passed from this face and ending abruptly about

the middle of the boss, the western half being unaffected. This would appear to show that the ice-flow took place from the east or north-east.

At Port Erin the rocks are of Silurian slate, inclined at a high angle, much contorted, and intersected by numerous veins of quartz. These are capped by beds of drift, which have not the characters of the true till as previously described. They consist for the most part of sandy clay, with many stones, mostly of slate and quartz, but mixed with granite, red sandstone and other rocks foreign to the locality, and there are few pebbles of limestone. The pebbles are usually pretty well rounded, but often show one or more rubbed faces, as is well seen in the granite boulders, while some which seem identical with the basaltic rocks of the Stack of Scarlet, are striated. A rough stratification is apparent, and in various places the uppermost portions consist of thin deposits of well rounded stones similar to those described as raised beach deposits at Port St. Mary, but devoid of cementing material. Boulders of fine-grained granite 18 in. or so in diameter occur. A large granite boulder some 8 ft. by 6 ft. is seen on the road from Port Erin to Bradda Head. It seems clear that these beds have been formed under different conditions from those under which the till was produced, and that water played a more prominent part in their arrangement.

In some places on the cliffs where these drift deposits are seen resting on inclined beds of slate, the latter seem much disturbed and broken up at the junction, and large fragments of slate are embedded in the sandy clay at all angles in a state of great confusion. In one case well rounded granite pebbles and a rounded block of red sandstone were mixed up with these pieces of slate. An explanation of this arrangement may perhaps be best found in the action of coast ice.

In the cliff against the life-boat house at Port Erin, Boulder-clay is seen resting on highly inclined thin beds of slate and shale. The edges of these thin beds are bent back through more than a right angle, and are fractured at the apex of the bend. The displacement is not due to a fall of rock, as it is directly opposed to the slope of the cliff. As far as I could ascertain the bending was towards the south-east, and it is worth noting that the direction of the force which caused this effect, so far from coinciding with the general direction of the ice-flow in adjacent districts, as indicated by the striæ and striated bosses, is almost exactly at right angles to it. Possibly in this case also coast ice may have been the agent by which the effect was produced.

SOME NOTES ON THE GEOLOGY OF ST. DAVID'S, PEMBROKESHIRE.

By T. Mellard Reade, C.E., F.G.S.

The long-continued and important labours of Dr. Hicks have invested the neighbourhood of St. David's, otherwise known for its architectural remains and antique sanctity, with a peculiar interest to geologists.

His ingenious investigations have done much towards raising up a peculiar school of geologists, and have drawn forth a considerable torrent of warm, not to say bitter controversy.

Speaking for myself, I confess I found it difficult to understand the points in dispute until I examined them personally on the spot. The Archæan School of Geology has rather clouded its work in a scientific phraseology difficult of comprehension by the uninitiated.

The very names Pebidian, Arvonian, Dimetian, represent no very clear concrete ideas to the ordinary stamp of geologist; so, having experienced the difficulty of framing a mental picture of these formations, it has occurred to me that I may try the *rôle* of interpreter to my brother geologists who have not had the opportunity of conquering in the field these little initial difficulties.

The peninsula of St. David's is a south-westerly prolongation of South Wales, and, with the exception of the Land's End, is the most westerly point in either England or Wales. It is a treeless undulating plateau surrounded by precipitous rocky cliffs, in which are numerous coves and creeks, some of them used as small harbours. At the extreme western point, and separated from it by Ramsey Sound, through which the tide "races," is Ramsey Island. The character of the country is not unlike parts of Anglesey and Wigtonshire, and it must have been in early times a very desolate place; just the sort of place that seems to have been preferred by the saintly recluses of a former age. There are to be seen many interesting relics of antiquity, for an account of which I must refer those interested to the excellent "Antiquities of St. David's," by the Rev. Basil Jones (now the Bishop of St. David's), and Dr. Freeman, the historian.

The plateau is intersected by numerous valleys having their outlets on the rocky coast, so that notwithstanding the general regularity of level of the country, driving involves a great deal of down-dale and up-hill work, so much so that it is generally held that there are seventeen hills in the sixteen miles' drive from Haverfordwest to St. David's. The cathedral of St. David's is built in one of these valleys, that of the Alan. Whether this singular site was selected from motives of

sanctity or because of the shelter afforded, or from both, I am not prepared to say. Judging from the state of the walls, the site has been singularly unfortunate as regards the foundations, which must be on either drift or alluvium. It would seem to be a very difficult thing to select a bad foundation where nearly all is rock as at St. David's, but our saintly predecessors were successful in accomplishing it!

Even at the present time St. David's is the most out-of-the-world cathedral city that I am acquainted with, and is not the sort of place likely to be affected by those exacting persons who cannot be satisfied with anything short of luxurious accommodation.

Before Dr. Hicks commenced his memorable investigations, no rocks older than the Cambrian were recognised in this area.

Much of what he calls Archæan was looked upon as metamorphosed Cambrian. This was natural, as at the time the Geological Survey was made the Cambrians were considered to be the lowest sedimentaries in the geological scale. The igneous rocks were thought to be intrusive, and therefore younger. It may be added that all the bedded rocks are thrown up at a high angle, and that there is apparently a general parallelism of the strike throughout.

Dr. Hicks, after many years' work in the district, arrived at the opinion that all the rocks below the quartzite conglomerate—a well-marked zone in the Cambrian—were pre-Cambrian, and he considered he could subdivide the pre-Cambrian into two stages, which he called respectively in descending order Pebidian and Dimetian.* Since then he has further refined upon this

* Q.J.G.S., 1876, pp. 229-39.

subdivision by introducing an intermediate stage, which he has christened Arvonian. *

He is of opinion that these pre-Cambrian stages are really important divisions separated from each other by distinct unconformities or by a peculiar system of faulting, which represents the same thing. To understand this in detail, it will be necessary to refer to his map. (Q.J.G.S., 1884, p. 560.)

It will thus be seen that the quartzite conglomerate is, according to Dr. Hicks, the base of the Cambrian; and he consequently calls it the "basal conglomerate." Much hinges upon this bed, and it is a singular thing that, while some geologists, following Dr. Hicks, see between it and the underlying rocks a strong line of unconformity, Dr. Geikie and several of the officers of the Geological Survey (all experienced surveyors) recognise nothing more than a few evidences of contemporaneous erosion, and in places a movement of the conglomerate upon the underlying beds. The Director-General of the Geological Survey, therefore, did not see his way to separate the conglomerate and overlying Cambrian rocks from the underlying volcanics. He considers that the one shades into the other, and claims them all down to Dr. Hicks' Dimetian as Cambrian, looking upon the Pebidian and Arvonian of Dr. Hicks as the oldest known Cambrian volcanic rocks.†

The Dimetian, Dr. Geikie brings a considerable weight of evidence to show, is an intrusive granite. Needless to say that Dr. Hicks entirely demurs to this destruction of his pre-Cambrian system, the building up of which has cost him many years' work.

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* Q.J.G.S., 1884, pp. 507-47.

† Q.J.G.S., 1883, pp. 261-383.

Since Dr. Geikie's examination another observer has entered the field—namely, Professor J. F. Blake,* who is satisfied of the existence of an unconformity between the Cambrian basal conglomerate and the underlying rocks, and apparently also of the faulting between the Dimetian and surrounding rocks, but considers that the Dimetian represents the core of a volcano somewhat in the same way as the granite of Mull does that of a Tertiary volcano, as shown by Professor Judd.

Like most geologists interested in these early rocks, I read the papers as they came out, but found it impossible to form any opinion of the relative weight of the arguments without studying the geology on the spot.

My object in visiting St. David's was not to join in the controversy, but simply for the purpose of self-instruction, an object I usually try to combine with my summer holiday; in fact I made up my mind before going to altogether abstain from writing on the subject.

Alas for these excellent determinations! I now find myself adding a few Archæan setts to the road to a certain place which is said to be paved with good intentions!

Outlines of the Geology of St. David's.

The whole of the bedded rocks, whether Cambrian or Archæan, are set up on edge at high angles. With one exception there is a remarkable parallelism of strike, and the axis of the group runs in a direction about east north-east and west south-west. The central portion, occupied by the presumably Archæan rocks, is about two miles wide, and these are flanked on either side by the undoubted Cambrians. At Caerbody Cove and valley and at Caer-fai the Cambrian succession upwards from

* Q.J.G.S., 1884, pp. 294-311.

the conglomerate is well seen. The rocks consist in upward succession, stated broadly, of green shales, purple sandstones and shales, and purple and green grits and shales. The dip of these rocks is usually towards the south, or south by east, but as the coast is followed westward the dip changes until it is reversed so that the conglomerate bed at the cove near Nuns' Chapel has a northerly dip. The northerly dip of the Cambrian green shales and purple sandstones and shales is also seen further westward in the harbour called Porth-clais. The Cambrian at Castell and Porth Stinian on the opposite flank of the Archæans dip to the north-west.

PEBIDIAN AND ARVONIAN.—For the purposes of this geological description I have assumed that the beds forming the central strip about two miles wide, and enclosed between the "basal conglomerate" on the opposite sides of the peninsula, are Archæan, but their title to that name will be afterwards discussed.

These beds are to be seen in the Caerbody valley and by Clegyr Bridge, and consist of volcanic breccias, porcellanites, agglomerates, and quartz felsites.

On the northern side of the axis the ashy breccias are not so distinctly bedded as those on the southern flank, and can hardly be said to be a repetition of the southern beds.

My object is not to give details—for these the student must consult the careful work of Dr. Hicks and Dr. Geikie—but to help any one who chooses to give the matter a little consideration to a general view, so that the points at issue may be understood and appreciated.

DIMETIAN.—At Porth-lisky a tongue of granitic rock, having a south-westerly direction in its major axis, intervenes between the Cambrian and the Archæan. As the Cambrian beds here strike east and west, it will be seen

that they run butt up against the granite. Connected with this is a boss of similar granitic rock in the valley of the Alan north of Porth-clais, having a diameter of about three-quarters of a mile. This granite seems readily decomposable, and is in fact cut through by the stream indifferently with the Archæan rocks higher up the valley, though these are on edge. A great deal hinges upon the interpretation of this granitic rock. Dr. Hicks considers it to be the oldest Archæan in the area, and has made of it a very important and distinct formation which he calls "Dimetian." He has shown it in his last map, surrounded by boundary faults which cut it off from the other Archæans and from the Cambrians. Whether these faults really exist, and the necessity for them on Dr. Hicks' interpretation of the rocks, will be discussed presently.

How the Beds came into their present position.

To arrive at a correct geological interpretation of this remarkable country it will be necessary to consider, to some extent, the dynamical *modus operandi* of nature. It may be taken as a well-established general proposition that beds are only thrown up to a vertical pitch by folding. No known system of faulting, we may rest assured, could possibly place the Cambrians and the Archæans of St. David's in their present highly-inclined position. It is, therefore, necessary to enquire whether these rocks represent one or more folds, or only a portion of a fold. The occurrence of the Cambrians on either flank of the central axis, and not in the centre, points to one fold. There is nothing in this inconsistent with what I saw on the ground, or with either Hicks' or Geikie's map, even if we admit the existence of the great longitudinal faults with which Dr. Hicks has separated

his formations. Now comes the crucial test of the "Dimetian." An older rock, separated from an overlying one by unconformities, might be pushed up so as to form a core by folding. If the Dimetian originally formed a ridge—as maintained by those who believe it to be an anterior formation, from which part of the materials of the Cambrian conglomerate was derived—the Cambrian beds must have been laid down against it in an approximately horizontal position. It must, in fact, with the Pebidians on its northern flank, have protruded through the conglomerate, even if afterwards covered by the later Cambrian beds. It is conceivable that the effect of folding on these combined beds and central mass of Dimetian would be to throw up the younger rocks on the flanks of the older, while the older island or core was being simultaneously pushed up.

If such a process had happened, the boundary of the Dimetian would show an irregular oval line corresponding to the original horizontal contours of the island—a line of unconformity emphasised by the movement of the rocks over it, with may be a fault-breccia between, together with slickensided faces. I venture to think, if this had happened, geologists would have found no difficulty in deciphering the relations of the rocks. This, however, is not what Dr. Hicks' map exhibits. On the contrary, he surrounds the Dimetian with sharp cut fault-planes like ordinary boundary faults. Such faults would mean that the Dimetian itself had been cut by the faults; and as it is shown in contact all through at every fault plane with rocks of other ages, it follows, on the hypothesis upon which alone the map can be accepted, that the severed parts of the Dimetian must have been left below deep down in the earth. As I have elsewhere attempted to explain, if we accept the theory

embodied in Dr. Hicks' map, the Dimetian must have been driven through the previously folded Pebidians and Cambrians like a plug.* The throw of the boundary faults, considering the vertical position of the beds, required by this supposition, is so great that it would have left on the rocks indelible marks of the movement had it taken place. We may also reasonably ask, if such a throw had occurred, how could the materials of the conglomerate have been derived from the Dimetian?

It will thus, on a little reflection, be seen that the map and the explanations of the geology in the text are irreconcilable with each other. The examination I made on the ground left me a total disbeliever in these great faults bounding the Granite or Dimetian.

Neither the theory of an island ridge of Dimetian pushed up as a core during the folding of the overlying rocks, nor the theory of faulting adopted in the map, are in my opinion consistent with the relations of the rocks and accompanying phenomena as seen on the ground.

That the granite or granitoid rock called the Dimetian is a post-Cambrian intrusive rock I feel satisfied. At all events the hypothesis meets the difficulties of the case in a more satisfactory way than any other yet offered.

Dr. Geikie arrived at this conclusion from his examination,† and urges strong reasons in its favor. The conglomerate in contact with the granite on the right bank of the Alan at Porth-clais is so hardened in places as to be one of the toughest rocks I ever attacked with a hammer.

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* Geol. Mag., Dec., 1887, p. 558.
† Q.J.G.S., 1883, p. 277.

To make a long story short, I fear we must give up the "Dimetian" of St. David's, and if so, the use of the name altogether.

Doubtless there are Archæan rocks elsewhere which occupy the geological horizon the Dimetian were supposed to represent at St. David's, but the retention of the name would only produce confusion.

Pebidians and Basal Conglomerate.—While Dr. Hicks' school maintain that there is an unmistakeable break or unconformity between the conglomerate and the volcanics, Dr. Geikie considers that there is a gradual passage upwards from the "Pebidians" or volcanics into the Cambrian, and claims the volcanics as Cambrian. I examined most of the junctions of the conglomerate with the Cambrians and volcanics, and while perceiving no strong and unmistakeable marks of unconformity, think that it will be better to separate the rocks below the conglomerate from those above it. In the Wrekin there is unmistakeable unconformity between the Archæans or volcanics and the overlying Cambrians, so that as the Pebidians of St. David's seem to represent a similar geological horizon, it will be well provisionally to call them both by the same name, and I see no reason, except the uncouthness of the term to English ears, why "Pebidian" should not be employed.

One of the great difficulties in deciding the question as to whether the Cambrian conglomerate represents a line of unconformity or not lies in the rapid way in which it thickens and thins out. On the coast near Nuns' Chapel the conglomerate bed stretches across the bay parallel to the coast in a peaked ridge, and at the western end it diminishes from at least 30 feet thick to 4 feet, as seen in the cliff, in a distance of about

60 feet. Again, the conglomerate is seen in the cliff at Ogfeydd-duo on Ramsey Sound. It is also seen outcropping in a pretty regular line inland, striking north-east, crossing the footpath from Rhossan to Porth Stinian.

Between the cliff at Ogfeydd-duo and the first outcrop on the north-east I searched in vain for any indications of it, so reluctantly came to the conclusion that it must have thinned out between the two, and disappeared at this particular spot. In this neighbourhood the conglomerate bed seems to overlap in succession several ash beds of the underlying volcanics, or, in other words, is transgressive upon them, and Dr. Hicks very naturally claims this as strong evidence of unconformity.

As regards the "Arvonian," better evidence will have to be brought forward than has yet been done to show that they really constitute a separate group.

The total geological results of the very interesting fortnight I spent at St. David's may be summed up as follows:—

The peninsula of St. David's represents principally a fold having highly-inclined beds greatly denuded and striking in a north-easterly direction. The fold is made up of Cambrian rocks on the extreme flanks, separated by a conglomerate bed from an interior set of beds consisting altogether of volcanic rocks, but that it is impossible to say at present what interval of time is represented by the break between them, and that probably the information must be sought elsewhere, perhaps at the Wrekin.

That the "Dimetian" is not an Archæan formation, but a granitoid rock intrusive in the volcanics and Cambrians, and therefore post-Cambrian.

While criticising in the interests of geological truth Dr. Hicks' work at St. David's, I need hardly say that I am fully alive to the value of the awakening he has assisted to produce in geological science by the ingenious and laborious work he has done at St. David's. That some of a man's work is wrong is no disparagement to him in my eyes; we are all wrong in a greater or less degree, and he who works out an original scheme for himself is necessarily more liable to pitfalls than one who merely traverses well worn ground.

GEOLOGICAL NOTES ON THE PRESTON DOCK WORKS AND RIBBLE DEVELOPMENT SCHEME.

By E. Dickson.

In my paper read before the Society last session, I described the character of the works now in progress at Preston, and the nature of the deposits met with in the course of the excavations. At that time the excavation for the river diversion had reached a point immediately under Castle Hill, on which Penwortham Church stands.

During the last twelve months the portion required to connect the new river diversion with the existing river channel has been excavated, and is now nearly completed.*

The deposits in the length last excavated are similar in character to those in the other portion of the river

* Since the paper was read the "Diversion" has been completed, and the river turned into its new channel.

diversion which have been already described. In this newly constructed length were found a boat, human skulls, and also skulls and bones of the *Urus*.

The upper portion of the sandstone rock consists of red sand generally from 1 to 3 or 4 feet in thickness, frequently containing embedded in it boulders of granite or felstones.

I mentioned in my former paper* the occurrence of a dome-shaped mass of rock 300 yards west of Hangman's Wood, having the appearance of a "roche moutonnée," and it seems probable that the red sand may owe its origin to the degrading action of the glacier or ice sheet which has undoubtedly passed over the surface of the sandstone.

During the last twelve months the Tidal Basin has been completed and the excavation for the 40-acre Dock proceeded with, but nothing has been met with to call for special remark. The deposits are similar in their sequence and mode of occurrence to those met with in the portions of the excavations described in my former paper. Bones, mainly of *Urus*, and Antlers of Red Deer, frequently occur, generally in the lower deposits of sand and gravel, and about 20 feet from the surface.

The following is a list of the bones already obtained from the excavations and now deposited in the Preston Museum, for which I am indebted to the Rev. J. Shortt, the Hon. Curator:—

53	Antlers (entire) Red Deer, almost all Royal.
35	Portions of ditto.
22	Fragments of ditto.
110	

* Proc. L'pool Geol. Soc., vol. v., p. 251.

1	Skull of Red Deer.
1	Lumbar Vertebra of ditto.
3	Sacral Vetebræ of ditto.
5	
43	*Urus* Skulls with horns.
2	,, Horns detached.
1	,, Thigh bone.
1	,, Lumbar Vetebra.
47	
5	Horses' heads.
2	,, jaws.
3	,, ,, (portions).
1	,, pelvis
6	,, ,, (portions).
1	,, ,, (large).
1	,, ,, (small).
1	,, rib (large).
1	,, ,, (small).
6	,, ,, (fragments).
2	,, leg bones (large).
1	,, ,, (small).
2	,, vertebræ of neck.
1	,, ,, dorsal.
7	,, bone fragments.
2	Skulls of Goat, horned.
2	,, Sheep, ,,
2	,, Pilot Whale.
1	,, Bottle-nosed Whale.
14	Human Skulls.
1	Jawbone of Razorback.
1	Vertebra ,,
63	

Making a total in all of 225.

The six human skulls found since the date of my previous paper have been measured by Mr. Shortt, with the following results:—

No. 11	found	4th April, 1887,	Cranial	Index		76·3.
„ 12	„	18th May,	„	„	„	79·5.
„ 13	„	16th June,	„	„	„	72·13.
„ 14	„	9th Dec.,	„	„	„	76·3.
„ 15	„	18th March, 1888,	„		„	83·0.
„ 16	„	„	„	„	„	78·18.

Two of the above skulls were found under Castle Hill, in the gravel lying above the rock, 2 to 3 feet above Ordnance Datum.

The collection of heads of the *Urus* obtained from these excavations is, I suppose, as a collection obtained from one locality almost unique, nearly 50 skulls and horns having been already found. The skulls occur of various sizes—from skulls, the incurving horns of which are 2½ feet apart, to those of which the horns are only 6½ inches apart.

At first, when skulls of such different sizes were found, it was thought that there might have been more than one species of *Urus* living in the same locality at the same time, and that this might help to explain the difficulty which naturalists have experienced in tracing the connection between the *Urus* and the old British Ox, from the latter of which the so called Wild Cattle of Chillingham are usually considered to be descended. But sufficient examples of *Urus* skulls have now been found to enable a series to be formed, shewing a regular gradation from the largest to the smallest. If, as I am inclined to think, the skulls all belong to animals of different ages but of one species, it goes to prove that the *Urus* lived and bred in the locality where the remains are now found. The degree, however, to which the horns of

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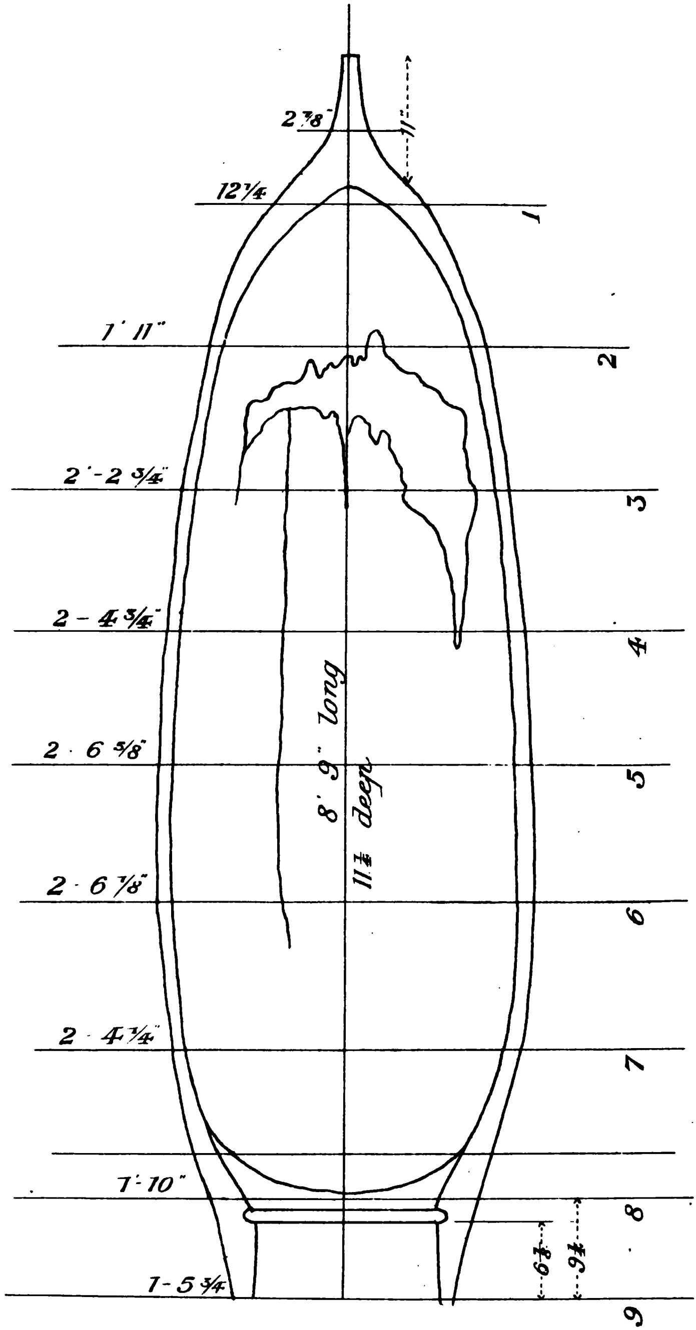

the smallest specimens are developed is a fact from which it might be inferred that the skulls belong to more than one species.

The boat or canoe, of which a diagram is given, was found on the 7th October, 1887, during the excavation for the river diversion. It lay 14 feet below the surface, 2 feet 6 inches above Ordnance Datum, 130 feet from the present river bank, 200 yards south-east of Castle Hill, and exactly opposite Messrs. Allsopps' shipbuilding works. The stern was placed at the root end of a tree, and was closed by a stern board almost entirely decayed, and which seems to have been composed of two planks, each half an inch thick, inserted parallel to each other in a groove at the sides and at the bottom. The length over all is 8 feet 8 inches, or 8 feet 2 inches from extreme stem to stern board. Abaft the latter are two holes, one at each side, $1\frac{3}{8}$ inches in diameter. The width at the top of the stern board inside is 1 foot 7 inches. The greatest width is at a distance of 5 feet 3 inches from the extreme end of the prow, where the boat is 2 feet 6 inches across, measuring from the outside of the gunwale. At 2 feet 6 inches from the prow the boat is 2 feet 1 inch across, and at 14 inches it is 1 foot 2 inches. The greatest depth is $11\frac{1}{4}$ inches. The prow projects 10 inches forward of the dug out portion in a sort of nozzle, in the under part of which is a round hole $1\frac{1}{4}$ inches in diameter. In the bottom, which is flat, and at the widest part, 1 foot 8 inches across, are two round holes, each 1 inch diameter. One of these is 2 feet 10 inches from the extreme prow, the other 6 feet 1 inch. The thickness of the sides varies from 1 to $1\frac{3}{4}$ inches. There is no trace of a rowlock or of thwarts. The boat is scooped, probably burnt, out of a single log of oak. It is very antique in appearance, but I think it

is almost impossible to form an opinion as to its exact age.

In addition to executing the Dock Works at Preston, the promoters of the scheme are undertaking the more difficult enterprise of making a waterway from Preston to the sea, navigable for vessels of large tonnage. To do this it is necessary to extend the existing training walls further into the estuary in the direction of Lytham, and to deepen by dredging the existing channel. Borings have been taken along the centre of the present channel, at low water, as far as seven miles from the entrance to the Tidal Basin, and a series of borings made very near to each other through the overlying sand to the gravel beneath, to ascertain the depth of the sand.

From these two sets of borings the section A has been drawn. In my previous paper* I referred to the fact that the surface of the sandstone rock slopes from the land to the sea, and that the gradient, being steeper than the river bed, the rock is not visible below the Tramroad Bridge at Preston. This gradual slope is well seen in the section taken through the Tidal Basin. At the Borehole No. 41 the rock is met with 25 feet below Ordnance Datum; but at the next boring (No. 45) a few feet only from the last, red sand (probably the upper layer of the pebble beds) is met with about 29 feet below Ordnance Datum, shewing probably the presence of a small fault between these two boreholes. Westwards from this last borehole (No. 45) red sand or rock is not met with. Borehole No. 47, which penetrates about 40 feet, passes into stiff red clay, which is probably boulder clay.

From Borehole No. 47 (about half a mile from the Tidal Basin) to Borehole 55 (about 2¼ miles) the deposits

* Ante, p. 253.

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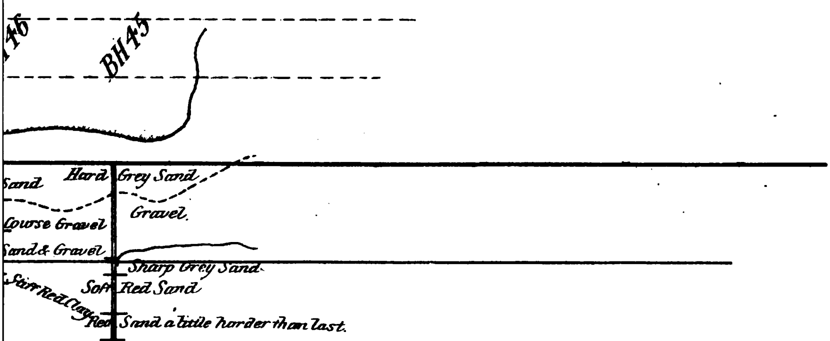

are grey river sand lying upon gravel, the latter containing boulders of granite and limestone, and are remarkably uniform.

From Borehole 56 to Borehole 59 a thick deposit of light blue clay occurs below the grey sand, and extends for about 1⅓ miles. At Borehole 61 (4⅓ miles from the Tidal Basin), at a depth of 22 feet below Ordnance Datum, a stiff red marl was met with. It gradually rises until, at a distance of five miles, the present surface is only 6 ft. 9 in. below Ordnance Datum.

Borehole 64 (5⅓ miles) passes through a dark brown loamy clay, and river silt and *no marl* is met with; but Borehole 65 (5⅔ miles) shews that marl is again present about 11 feet below Ordnance Datum. These beds of red and blue marl, mixed with gypsum, continue until a point about 7¼ miles from the Tidal Basin is reached, where they are lost sight of.

It is the removal of this mass of marl (undoubtedly Keuper marl), which stretches as a great dam across the river, that has been the cause of so much trouble and expense. It is described as "almost as hard as rock, and so hard as to tear the steel lips from the buckets of the dredgers as if they were made of tin, and requires the most powerful machinery to dislodge it." The scour of the river and tide seems to have no effect on it whatever. On the surface of the marl and in the gravel are boulders of granite, of which many have been brought up over two tons in weight.

But how has the gap in the marl, disclosed by Borehole 64, been formed? It is possible that the river itself has changed its course, and bending southwards excavated a channel through the marl. But it is a remarkable coincidence that the gap in the marl occurs exactly opposite the point where the River Douglas enters the Ribble, and it is not unreasonable to suppose

that this gap in the marl has been caused by a body of water moving at right angles to the present channel of the Ribble. A body of water moving in this way would have a greater excavating power than water whose velocity had been to a certain extent checked by a bend, as would have been the case if the gap indicates a former channel of the Ribble.

If this supposition is correct, and the gap in the Keuper Marl, disclosed by the boring, is due to water flowing from the south side of the estuary into the Ribble, it seems to throw light on the history of the Ribble Estuary, and its former physical geography. For (1) if this channel was excavated through the Keuper Marl by water, of which the Douglas is now the representative, the river Ribble must have flowed in a deeper channel, and nearer to the north side of the estuary than at the present time. (2) The southern part of the present estuary would then be dry land, through which the river cut its channel to the Ribble. To effect this the land would require to be more elevated than at present, as was the case during the period of the forest beds. During the succeeding periods of depression this river bed and also the Ribble bed would be silted up and the estuary commence to form.

I trust that further boring will be made during the progress of these works, and I think that if these are made they will shew a former bed of the river Ribble to the north of its present bed, into which the channel shewn by the boring No. 64 leads, cut through the bed of Keuper Marl, and which may be regarded as its pre-glacial course.

I again wish to express my thanks to Mr. Beckett, the engineer on the works, for supplying me with the details of the borings, and other valuable information.

NOTES ON A LARGE BOULDER FOUND IN DRIVING A SEWER HEADING IN OXFORD ROAD, MANCHESTER.

By T. Mellard Reade, C.E., F.G.S, &c.

A sewer is now in course of construction in Oxford Road, Manchester. It is situated on the Owens College side of the road, and is being put in by means of headings driven from shaft to shaft. About 200 yards beyond Owens College, as it is approached from the city, a large boulder obstructed the works. The contractor was, I believe, about to dispose of it very irreverently by blasting —a summary proceeding from which it was rescued by local geologists.

I examined the boulder on February 20th, 1888, and found that Messrs. Whitworth, the great gun factors, had been engaged to extract it from its subterranean position, and place it in the grounds of Owens College.

The level of the bed of the boulder was about 33 feet below the surface of the street. A shaft about 12 feet square had been sunk down to it, and as it lay partly towards the centre of the street the boulder clay had been excavated around and over it, so that it lay in a sort of cave.

I crept round the boulder, and examined it as well as I could in so dark a place. It was standing on screw jacks, having been lifted bodily two feet from its bed, preliminary to moving it laterally to get it under the shaft, over which a strong framework of timber baulks had been built to carry the crab for lifting it above the street level.

The boulder measures in extreme dimensions 9 feet 6 inches by 7 feet 4 inches by 5 feet 7 inches, according to information since received. I found on trial with a tape that it girthed 28 feet. Taking it as a circle 9 feet diameter and 5 feet thick, it would cube up to 318 feet, which at 13 feet to the ton gives 24 tons as its weight. It cannot be less than 20 tons.*

According to Professor Judd, who kindly examined the rock for me microscopically, and whose report I append, it is a much altered porphyrite, and was originally an andesitic lava.

The surface of the stone appeared to be polished and striated, not in planes, but moulded to the form of the stone.†

It was lying flat-ways in a bed of gravel and shingle, in which near or at the bottom of the boulder was intercalated a seam of laminated clay from 3 to 4 inches thick, but whether this extended beyond the boulder was not apparent. I exhibit chips from the boulder, and also a piece of the laminated clay and gravel below, the matrix of which is largely made up of broken and disintegrated sandstone. The gravel bed was 4 feet thick from the bottom of the boulder to the top of the bed, and an unknown thickness below it. I am informed, however, that the rock was probably within 3 feet of the bed of the boulder, as the sewer was driven in the rock a few shafts nearer to Owens College.

The upper surface of the boulder was embedded in stiff Boulder-clay, which extended upwards nearly to the street surface.

* The specific gravity, I am informed, is 2·74, and the rock contains 63 per cent. of silica.

† Our President, Mr. Beasley, who has seen the boulder since it was safely deposited in the grounds of Owens College, tells me that the top and bottom are smoothed and striated, one parallel to the longer axis, the other obliquely to it, and that it appears to have been weathered before it was striated.

The deposit in which it rested undoubtedly belongs to the Low-level marine Boulder-clay and sands, and the boulder is remarkable as being the largest I have met with in these glacial deposits. The one found at Edge Hill, and now in Sefton Park, weighed about 7 tons, so the Manchester boulder is about threefold its size. When safely landed on the surface it will be much better for inspection, but a view of it in situ was an experience worth the dirt and difficulty of the subterranean crawling it involved.

Report on the Rock by Prof. J. W. Judd, F.R.S.

The rock is a much altered porphyrite, and was originally no doubt an andesitic lava. It presents the zonel plagioclastic felspars, with numerous inclusions so characteristic of the andesites. The rock is much altered, and the ferro-magnesian silicates modified past recognition, but the general habit of the rock suggests that it was a pyroxene-andesite rather than a hornblende or mica-andesite. The felspars have been largely converted into viridite, and this substance has in turn given rise to the formation of much beautifully crystallized epidote, which is very conspicuous in the rock. The rock is very similar to some of the Lake-district volcanic rocks, especially to that of Eycott Hill, which has been very fully described by the late Mr. Clifton Ward and by Professor Bonney. I think there is little doubt that it came from the Lake-district.

John W. Judd.

EXAMINATION OF QUARTZITE FROM NILLS HILL, PONTESBURY.

By P. Holland, F.I.C., F.C.S., and E. Dickson.

The specimen of rock examined was obtained from the quarries at Nills Hill, Pontesbury, the northerly extremity of the Stiper Stone Range. It is there largely quarried for road metal, and is a compact, fine grained quartzite.

These rocks are described by Murchison,* who calls attention to the ripple markings on the surface of the beds, and the casts probably of sea-weeds.

Dr. Ricketts † refers to the quartzite rocks at Nills Hill as containing cracks, fissures, and cavities filled with a bituminous substance, and suggests that the bitumen found in the crevices of the rocks of the Longmynd Shales, at Haughmond Hill and other localities, may be due to the decomposition of the vegetable matter in the coal strata once situate above them but since removed, and from which it percolated through the strata to the fissures in the rock beneath.§

The quartzite in question does not differ in appearance in any marked manner from the generality of quartzites and grits of Archæan or Palæozoic age. A section of the quartzite was cut and microscopically examined by Mr. Rutley, who says with regard to it:—

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* Silurian System, 284, 285. Siluria, 5th Edit., p. 40.

† Proc. L'pool Geol. Soc., vol. v., p. 131.

§ As to M. Abich's theory on the origin of Bitumen, see Murchison, Siluria, 5th Edit., page 27 (Note).

" The rock appears from the section to consist mostly " of quartz grains shewing the original rounded forms of " the grains with subsequent enlargements of the quartz, " the latter having often developed crystalline faces, and " having the same optical orientation as the enveloped " grains. The section exhibits some very clearly defined " enlargements of this kind similar to those described " by Irving and Van Hise.* Fragments of felsite are " also present, and the section contains a very few grains " consisting of triclinic felspar. No graphite is to be " recognized, but it is possibly disseminated in the con- " dition of fine dusty matter, with which the section is " more or less strongly interspersed. Slight stainings of " ferric oxide are here and there visible, especially round " the borders of the crystalline grains and fragments " which compose the rock. In the felsitic fragments the " felspathic portions appear in small, nearly opaque, " flecks, which are seen by reflected light to be white or " yellowish, and which must be regarded as resulting " from the alteration of the felspathic matter into " kaolin."

A chemical analysis of an uniform sample of the quartzite was made, in which both the fusion and HF. methods of treatment were employed.

The following numbers were obtained :—

SiO_2 (Silica)	94·850
Al_2O_3 (Alumina)	2·380
Fe_2O_3 (Ferric Oxide) ...	0·619
K_2O (Potash)...........	0·668
Na_2O (Soda)	0·712
Carbon....................	0·070
Combined Water	0·627
	99·926

* Bulletin No. 8, U. S. Geological Survey.

The carbonaceous matter was separated by means of hydro-fluoric acid, for which purpose a specially-prepared solution was used. The black matter separated in this way from the silica and other constituents, was thoroughly washed with HCl, to remove all soluble salts, and finally collected in a previously-weighed platinum dish, in which it was dried at 120° C., and weighed. The dish was then heated to redness, and when cold weighed again, the difference in weight representing volatile matter. Five grams of the quartzite gave 5·1 milligrams of carbonaceous matter, or 0·102 per cent. Another portion of the sample yielded 0·096 per cent. when similarly treated. The black residue obtained in the way described was entirely volatile on heating the dish to redness. A portion of this black matter from a second operation deflagrated when thrown on fused nitre, and gave the familiar reactions for CO_2 when burnt in a current of pure air, the products of combustion being passed into baryta water. These experiments shew, then, that the black matter, if not consisting entirely of carbon, undoubtedly contains this element. The sample of the quartzite which was analyzed, and in which carbonaceous matter occurred, was a piece of compact quartzite, which had been specially washed before being analyzed, and was entirely free from cracks and cavities into which carbonaceous matter in a bituminous form could possibly have percolated from overlying beds. The carbonaceous matter was in the substance of the rock itself, and its mode of occurrence is altogether distinct from that of the bituminous matter in the cracks of the quartzite, and the crevices in the Longmynd shales, as described by Dr. Ricketts.

Many competent authorities consider that there is "no other source of unoxidized carbon in rocks than that

"furnished by organic matter which has obtained its "carbon in all cases from deoxidation of carbonic acid "by living plants."*

This conclusion is questioned by Whitney and Wadsworth,† who refer to the separation of graphite in melted iron as it cools, and its presence in furnace slags, as evidence that carbon can be formed in contact with the oxides of iron in a melted state. But without going minutely into the question, it may be pointed out that the conditions under which graphite is found in blast furnace products are not identical with those under which, according to Bischoff, the carbon is found present in rocks; for the graphite in the furnace products is, in all probability, produced by the reducing action of the melted metal on the furnace gases, and it must be remembered that the carbonic oxide largely composing these gases is the first product of the oxidation of the fuel.

If we are to accept the theory that the origin of graphite, usually locally distributed in a rock, is to be ascribed to the reducing action of some metal, notably iron, in a state of fusion on CO or CO_2, ought we not invariably to find with the graphite so formed, a weight of metallic oxide bearing some numerical relation to the carbon set free? In the best qualities of graphite, however, the oxide of iron is so small in amount, that it may be set down as an accidental impurity.

Again, graphite is frequently found apart from melted metal, in which case some further explanation must be sought.

*Dawson, Geol. Hist. of Plants, p. 12. Bischeff, Chem. Geol., vol. I., p. 251. Sterry Hunt, Chem. Essays, p. 301. Phillip's Geology (Seeley & Etheridge Edit.), p. 23.

† Azoic System, p. 538.

Reverting again to the Nills Hill stone, it is highly improbable that the carbon found in this rock is the result of the deoxidation of carbonic acid by melted metal, and it is much more reasonable to suppose that the carbon is derived from the deoxidation of the carbonic acid by vegetable life. And if this supposition be correct, the hypothesis—that the casts are those of sea-weeds, or other forms of plant life—is greatly strengthened.

ON THE COLOURING MATTER OF THE MINERAL "BLUE JOHN."

By A. Norman Tate, F.I.C., F.C.S., &c.

The mineral "Blue John," found in considerable quantity in Derbyshire, possesses many peculiarities of colour, the usual tints being more or less purple. This colour runs in fine streaks or in bands, and associated with the purple colouring matter there is not unfrequently a reddish-yellow colouring substance, while the other parts of the mineral are almost colourless. The gradations of colour give the mineral an appearance sufficiently attractive to have brought it into use for many ornamental purposes.

What constitutes the colouring matter has not, as far as I am aware, been definitely ascertained, and therefore I will give the results of a few experiments made in my laboratory, with a view of ascertaining the composition of the colouring substance. When the mineral was heated in a flask there was noticeable a peculiar odour

indicative of organic matter, but no volatile products could be collected. This heating quite destroyed the colour, and on cooling it was not restored; but when the residue was moistened with a little distilled water, it changed from a white to a light straw colour, indicative of the presence of a minute quantity of iron.

Tested for Manganese, not a trace was found.

On heating a considerable quantity of the spar in a platinum dish with strong sulphuric acid, reactions took place indicating the presence of organic matter, and on drying the mass and igniting, the black colour at first produced was entirely destroyed; and when the residue was boiled with hydrochloric acid, and the solution afterwards treated with ammonia in excess and filtered, the filtrate was found to be slightly coloured yellow, but contained no iron or other metals that could give a colouring substance. But the residue on the filter gave decided evidence of the presence of iron.

A comparative test of the coloured and uncoloured portions of the "Blue John" showed that the uncoloured portions contained only about one-fourth the proportion of iron found in the coloured portions.

Considering these and other results obtained, I am led to believe that the colouring matter consists largely of organic, or hydrocarbon matters, which are destroyed on heating, but that there is in it also a minute quantity of iron.

Time has not allowed me to go as fully into the nature of the organic matter as I could wish, but I hope to report further before long.

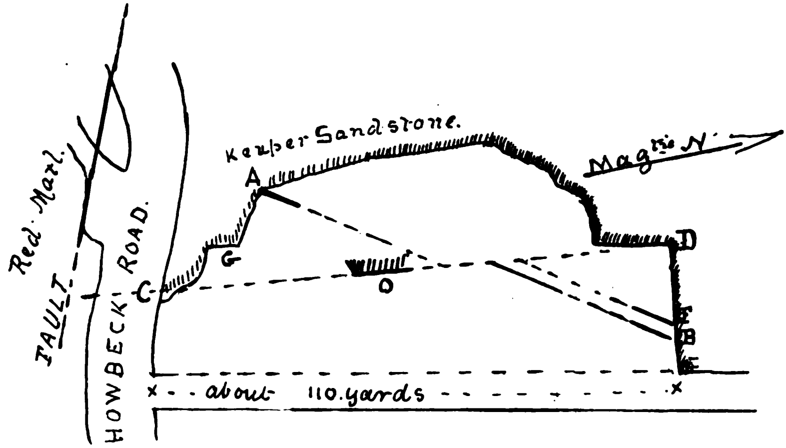
SOME IRREGULARLY STRIATED JOINTS IN THE KEUPER SANDSTONE OF LINGDALE QUARRY.

By H. C. Beasley.

In a paper read last session I described a horizontally striated joint extending across a quarry near St. Aidan's College, Birkenhead, known as Lingdale Quarry. Since then a series of slickensided faces has been exposed on the west side of the Quarry, shewing striations in varying directions within a very short distance of each other. The principal faces are at the base of the section extending to a height of from 4 to 8 feet; the joint or joints are nearly vertical, and the total length of the section is about 10 yards. I have numbered the faces 1 to 4 from North to South. (See diagram.) No. 1 is close to the fault marked A. No. 2 rather more than a yard in the rear of No. 1, and nearly parallel with it. The striæ on these joints also coincide in direction; the face curves somewhat to the South. No. 3 is a few yards from No. 2, and is probably part of a joint a few inches in the rear of it, but it is not traceable in the intervening space. No. 4 is apparently continuous with No. 3, but not quite in the same plane, being bent very slightly back (towards S.W.). I have not been able to trace any of the striæ from one face to the other. It will be noticed that the direction on Nos. 3 and 4 is entirely different from Nos. 1 and 2.

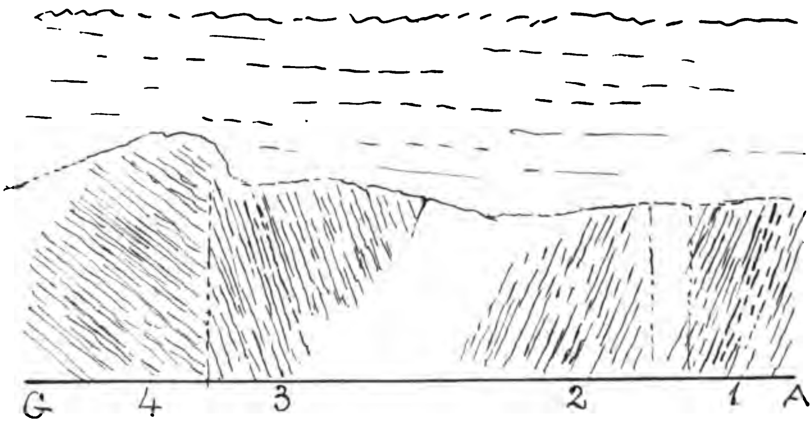
No. 1.	Striæ slope towards	E. by S.	25°	from vertical.
2.	,,	,,	25°	,,
3.	,,	N.W. by W.	15°	,,
4.	,,	,,	50°	,,

Above these faces there are several patches of slickensides with the striæ more nearly vertical.

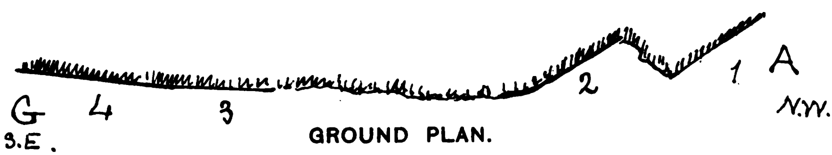


PLAN OF LINGDALE QUARRY, BIRKENHEAD.

DIAGRAMS SHOWING RELATIVE POSITIONS OF FACES NOS. 1 TO 4, AND THE DIRECTION OF THE STRIATION ON EACH. LENGTH OF THE SECTION, ABOUT 10 YARDS FROM N.W. TO S.E.



FACE OF SECTION.



GROUND PLAN.

The fault marked A is apparently the same as that marked B on the north face of the quarry; both have the same direction and hade 20° East, but they are not on the same line, having apparently been thrown out by the North and South movement along the horizontally striated joint C O D, formerly described. There is nothing to shew the amount of vertical throw at A, but at B it is about 2 feet, and the face of the fault is obliquely striated 25° from vertical towards the North; some indistinct striations on A are 35° from vertical in the same direction; there is about 4 feet of fault rock. About 3 feet west of B a close joint F is visible at the upper part of the section parallel to the fault, and shewing a throw of 6 inches; it is scarcely visible in the lower part of the section, but is plainly shewn where the floor of the quarry has been worked. The joint has cut cleanly through numerous nodules of light grey clay, and each half has left a very distinct streak on the opposite face of the joint. These are the width of the clay nodules, and mostly about 6 inches in length, never exceeding this, which corresponds with the throw as shewn above, and their direction is exactly the same as the striations on the fault B.

The joint C O D does not form a straight line; the part O, exposed in the middle of the quarry, being 3 or 4 yards to the East of a continuation of the striated face at D. The joint is clearly marked at C, which is in a line with O. The horizontal movement of the fault A B would not be sufficient to cause this displacement; so either the joint is not straight, or C O is a second joint parallel to D, but I could find no trace of it on the northern end of the quarry. Numerous crystals of Barytes were found at O.

N.B.—All the above bearings are magnetic.

REPORT OF EXCURSION ALONG MERSEY TUNNEL EXTENSION AND WIRRAL RAILWAY.

MARCH 26th, 1887.

THE attention of the members was in the first place directed to some effects resulting from the construction of the extension of the Mersey Tunnel towards Birkenhead Park, and afterwards to the cutting for the Wirral Railway between the terminus of the Tunnel and the Docks Station.

The Tunnel, having passed beneath Hamilton Square and Argyle Street as far as the goods line of the Birkenhead Railway, leaves the Triassic Sandstone, and at a great depth—say 60 feet or more—enters glacial deposits, and during almost the whole of its course passes through a bed or beds of loose sand and some gravel lying between the Sandstone rock and the Boulder-clay. The tendency which this loose sand had to "run" rendered the construction of this portion of the work exceedingly difficult, and probably more engineering skill was required to overcome this difficulty than in making that beneath the waters of the Mersey. This was rendered evident throughout its course by the cracks and fissures in the walls of houses, and the subsidences of the roadway and parapets. The Wesleyan Schools shewed a large open crack from top to bottom, and still more extensive damage was caused to the Roman Catholic Church of St. Lawrence. Though the excavations were carried on at a great depth (60 feet), it was requisite to carry on the operations by a temporary open cutting.

The open cutting is made in Boulder-clay, and near the Docks Station through silt which had been excavated from Wallasey Pool in the construction of the Birkenhead Docks. The most remarkable phenomenon disclosed occurred at Duke Street, the site of the Park Station. It consists of a large accumulation of sand embedded in Boulder-clay. In the direction of the cutting the sand appeared as if it had been deposited in a channel previously formed in the Boulder-clay. In the opposite direction, across the line, the bottom of the cutting is formed of Boulder-clay, on which rests this unconsolidated sand. The top of the sand is very irregular, and has processes from the Boulder-clay which overlies it extending into its substance, and blocks of the clay are likewise embedded in it. There were slight signs of bedding in the sand, but the dip was in different directions. This accumulation was not dropped, as I have considered many blocks of sand have been, from bergs or floating ice; but appears as if it were formed in an interval of the deposition of the Boulder-clay and subsequently had been much disturbed, as if by pressure.

Another accumulation of sand rested against a perpendicular bank of Boulder-clay. There was also exposed a bed of sand and gravel, with fragments of shells, at least a foot thick and 18 or more yards in length. It was situated at the bottom of the cutting, so that there may have been a greater thickness below; but the upper surface is so horizontal for this distance, that the probability is that it is situated where formed, and has not dropped from floating ice.

C. RICKETTS.

REPORT OF FIELD MEETING AT WALLASEY.

MARCH 26th, 1887.

THE members of the Society (after inspecting the cutting of the Mersey Railway under the leadership of Dr. Ricketts) were conducted to the quarry near the windmill at Wallasey. On the way we visited the quarry at Poulton, but nothing of interest had been exposed since our visit there in 1885. At Wallasey I was able to point out four or five parallel joints having an east and west direction, as described in my paper published in the last number of the Proceedings. All were distinctly slickensided and striated horizontally, and in some instances traceable for a considerable distance, whilst they were crossed diagonally by a similar joint exposed on both sides of the quarry. The main feature of interest, however, was the disturbed state of a bed of conglomerate and a bed of grey shale, which disturbance was, I consider, probably in some way connected with the same lateral movement cf the rocks that caused the horizontal striæ on the faces of the joints. The bed of grey shale was torn up, and fragments embedded in various positions in the conglomerate, and the whole apparently consolidated by the pressure of the superincumbent rock and the infiltration of iron. These beds, it was pointed out, are close to the base of the Keuper. The actual base was, however, not shewn in the section, but the Bunter is visible at a short distance.

H. C. BEASLEY.

REPORT OF FIELD MEETING AT HILBRE ISLAND.

JUNE 4th, 1887.

THIS excursion was made in conjunction with the Liverpool Biological Society.

The combined party proceeded from West Kirby across the shore to the Middle Island, where at the base of the cliff, on the west side, is

a conglomerate bed to all appearances principally made up from the destruction of the Triassic beds below. Upon this lies a current bedded sandstone resembling the Cheshire Keuper, and at one place a thin bed of current-bedded gravel intervenes between them. Further north the soft red sandstone (Bunter) rises above the shore level, the conglomerate bed thinning, and the grey current-bedded Keuper continuing as before.

At the south end of the North Island the conglomerate bed rises to the westward, displaying a deeper section of the soft red Bunter sandstone, with the Keuper above as before. The conglomerate bed was found to be very persistent, and composed largely of Triassic sandstone pebbles, with some of quartzite. The sections were considered to be very instructive, as shewing the relation between the Bunter and the Keuper.

T. MELLARD READE.

REPORT OF FIELD MEETING AT RUNCORN.

JULY 2nd, 1887.

The party, which was led by Mr. Charles Timmins, of Runcorn, first examined a section in the Goods Station Yard, where the Keuper marl was seen resting on the Waterstones, and those again on the Lower Keuper Sandstone. They then proceeded to view a remarkably fine section in the railway cutting (in Norman Road), where the marl is thrown down against the sandstone, the fault being built up in the sides of the cutting. Mr. Timmins stated that a boring some short distance to the south-east of the fault passed through 240 feet of marl, and proved 80 feet of waterstones. The main fault which brings the marl against the sandstone was afterwards seen in the fields beyond the waterworks, where a marl pit was observed within a few yards of the sandstone seen in section on the side of the road.

Runcorn Hill, composed of Keuper Sandstone, was visited, and a halt made for some time on the summit to observe the general features of the Mersey and Weaver valleys, so well seen from this point. Several extensive quarries in the hill were next examined, very extensive and fine sections of sandstone being displayed. It was pointed out that good building stone is obtained at two different horizons, separated by a sandstone (locally termed "fay") which is not obtainable in large blocks, and is almost useless as a building stone. The master joints in the quarries run in a north and south direction, and are crossed by a secondary series at right angles. The sandstone is remarkably even-bedded, and free from faults. Partings of marl occur in places, and the joint faces are often coated with a layer of marl. Ripple marks and sun cracks were observed in these shaly partings, but so far as could be ascertained no footprints have been found.

W. HEWITT.

REPORT OF FIELD MEETING AT ST. HELENS.

OCTOBER 1st, 1887.

The last Field Meeting of the season was held in the neighbourhood of St. Helens, to visit the excavation at Cropper's Hill, known as Doulton's Delph. A number of coal seams were to be seen on three sides of the quarry, and those nearest were carefully inspected. Splendid specimens of Stigmaria were observed running into the "warrant," or underclay. A very fine trunk of Araucarioxylon was also noticed in situ. Fossils were not to be found so abundantly as on former occasions. In one band many good and large specimens of Anthracosia were obtained. This band consisted to a very great extent of nodules of impure ironstone, and seemed to contain Anthracosia in abundance. There are many similar bands in the district, and by the miners of this neighbourhood they are commonly known as "cockle-shell" beds. At a point lower down the quarry the shale appeared to be full of the remains of ferns and Calamites. This spot has yielded some really good specimens of Sigillaria, Halonia, Lepidodendron, Calamocladus, Cordaites, Psygmophyllum, and Volkmannia, besides those which have already been mentioned. Messrs. Morton and Marrat, who saw some of the fern specimens collected by me at different times from this locality, remarked that they were similar to those found at Ravenhead by the Rev. H. H. Higgins, although not discovered on the same horizon.

By the kind help of Mr. G. H. Morton, F.G.S., some idea was obtained of the precise position of the strata exposed. Immediately beneath lies the Rushey Park Coal. In the centre of the quarry near the top, where the bed was thickest, the grit appeared to have been subjected to pressure. On the left side of the quarry at the top, a coal seam was seen to have been caught at the outcrop and bent back upon itself. The same phenomenon was noticeable in the superincumbent clay and the underlying shale immediately accompanying the coal. The general dip of the strata is to the E.S.E., at an angle of about 16 degrees. In the Boulder-clay which covers the strata here a number of stones occur, which exhibit traces of glacial action. They are mostly limestones and rounded portions of rocks characteristic of the Lake District. Some specimens of granite and diorite were found to be greatly decomposed. In the red clay at the surface some few bones have been discovered, but they do not appear to be very old. A short distance away from the quarry the Coal-measures are cut off by a great fault.

S. GASKING.

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*MARRAT, F. P., 21, Kinglake Street.
MANSELL, Rev. J., 10, Kremlin Drive, Stoneycroft.
*MOORE, T. J., C.M.Z.S.L., 14, Gardner Road, West Derby.
Liverpool Museum.
MORTIMER, Captain, Liverpool.
*†MORTON, G. H., F.G.S., F.R.G.S.I., 209, Edge Lane.
NEWALL, E., 14, Elm Grove, Tranmere.
PATERSON, J., C.E., F.G.S., Palmyra Street, Warrington.
PALMER, S. J., M.B., M.R.C.S., Netherfield Hospital.
*†PICTON, Sir J. A., F.S.A., Sandy Knowe, Wavertree.
4 and 5, Queen Buildings, Dale Street.
*POTTER, C., 101, Miles Street.
*†READE, T. M., C.E, F.G.S., Park Corner, Blundellsands.
Canning Chambers, 4, South John Street.
RHEAM, W., B.Sc , University College, Ashton Street.
*†RICKETTS, C., M.D., F.G.S., 18, Hamilton Square, Birkenhead.
*†ROBERTS, I., F.G.S., Kennessee, Maghull, Lancashire.
39, Gardner's Row.
RICHARDSON, W. A., C.E., Valley Lodge, Borough Road, Birkenhead.
ROBINSON, J. J., Blundellsands Road, Great Crosby.
SHONE, W., F.G.S., Upton Park, Chester.
*TATE, A. NORMAN, F.I.C., F.C.S., F.G.S., 9, Hackins Hey.
*TATE, G., Ph.D., F.G.S., F.C.S., Liverpool College of Chemistry.
96A, Duke Street.
*TIMMINS, A., C.E., Stanley Villas, Runcorn.
TUNSTALL, J., 45, Vine Street.
*WARD, T., Brookfield House, Northwich, Cheshire.

ASSOCIATES.

MORTON, Miss S. E., 209, Edge Lane, Liverpool, E.
ROBERTS, Mrs., Kennessee, Maghull, Lancashire.
READE, Mrs., Park Corner, Blundellsands.

* Have read Papers before the Society.
† Contribute annually to the Printing Fund.

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